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AFTER OPERATIONS REPORT

1ST ENGINEER ARCTIC TASK FORCE

RESEARCH AND DEVELOPMENT PROGRAM

[redacted]

GREENLAND 1955

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AFTER OPERATION REPORT

1st Engineer Arctic Task Force

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INTRODUCTION

The 1st Engineer Arctic Task Force was organized at Fort Belvoir, Virginia during the early part of 1954 for the specific mission of co-ordinating, supervising, and providing logistical support for the Corps of Engineers Research and Development Program in Greenland.

During the early summer of 1954 the Engineer Research and Development program was initiated in Greenland with 75 enlisted men and 4 officers comprising the strength of the Task Force. Technical personnel and scientists were provided by the four Engineer Research and Development agencies, the Engineer Research and Development Laboratories (ERDL), the Snow Ice and Permafrost Research Establishment (SIPRE), the Waterways Experiment Station (WES), and the Arctic Construction and Frost Effects Laboratory (ACAFEL). This first season served to acquaint personnel from the Task Force and from the research agencies with the conditions, terrain, and problems peculiar to Greenland. In addition considerable work was accomplished on fourteen specific projects.

The 1955 season continued the work started in 1954 and also launched two additional projects, which brought the number of active projects to sixteen. In spite of late approval of the 1955 program and a critical shortage of personnel, program objectives were accomplished successfully, and planning for the 1956 program was commenced during July of 1955.

This report discusses briefly the scope, objectives, and significant accomplishments of the 1955 program and enumerates the problems encountered and the solutions applied or recommended for future years.

Scientific project reports will be prepared at a later date by the research agencies involved.

HEADQUARTERS
1ST ENGINEER ARCTIC TASK FORCE
FORT BELVOIR, VIRGINIA

AFTER OPERATIONS REPORT
ENGINEER RESEARCH AND DEVELOPMENT PROGRAM
GREENLAND 1955

SECTION I

GENERAL

1. Authority

a. Joint letter to Chief of Transportation and Chief of Engineers, dated 8 March 1955, File No. CSRO/F, from Chief of Research and Development, Department of the Army, Subject: Consolidated Army Research and Development Program, Icecap, 1955.

b. Letter, Office of the Chief of Engineers, ENGNB, dated 8 April 1955, Subject: Authority for CofEngrs R&D Program in Greenland, Summer 1955.

2. Scope

a. The proposed scope of this program is outlined in Abbreviated Conference Notes on Corps of Engineers Greenland Program, Calendar Year 1955. These notes are based on a conference held at OCE 25-26 January 1955.

b. The program was accomplished as described in Section III and Annexes A through N of this report.

3. Mission of the 1st Engineer Arctic Task Force

a. To provide command and staff supervision, coordination, planning, and administrative and logistical support for the 1955 Engineer Greenland Research and Development Program.

4. Mission of the R&D Agencies (ERDL, SIPRE, WES, ACAFEL)

a. To accomplish programmed project work as outlined in conference notes referenced in paragraph 2a above.

b. To provide scientific and technical personnel for scheduled projects.

c. To collect, evaluate, correlate, and compile scientific data, and to produce reports required by OCE.

5. Chronology:

a. Commanding Officer of the 1st Engineer Arctic Task Force and dates of incumbency:

(1) Lt Col Arthur H. Lahlum - 1 January to 30 April 1955.

(2) Lt Col Elmer F. Clark - 1 May 1955 to present date.

b. The first planning conference with Research and Development agencies was held at OCE on 25-26 January 1955.

c. The Engineer Research and Development Program, Greenland 1955 received official approval on 8 March 1955.

d. The 1st Engineer Arctic Task Force moved from Fort Belvoir, Virginia, to Thule, Greenland, by air in six increments on the following dates:

1st Increment - 12 April 1955

2nd Increment - 15 April 1955

3rd Increment - 30 April 1955

4th Increment - 31 May 1955

5th Increment - 5 June 1955

6th Increment - 10 June 1955

e. The mission of the 1st Engineer Arctic Task Force was carried on at full strength of seven officers, two warrant officers, and one hundred and seventy-two enlisted men from 12 June until 25 September 1955.

f. The movement from Thule, Greenland, to Fort Belvoir, Virginia, was made by the 1st Engineer Arctic Task Force in three increments on the following dates:

1st Increment - 26 September 1955 (by air)

2nd Increment - 2 October 1955 (by water)

3rd Increment - 20 October 1955 (by air)

1ST ENGINEER ARCTIC TASK FORCE
ADMINISTRATION
SECTION II

1. Organization:

a. The Task Force provided for support of the 1955 Greenland Research and Development Program consisted of two distinct units, the 1st Engineer Arctic Task Force, a unit containing four officers and seventy-five enlisted men, and the 546th Engineer Company (Service), a unit containing three officers, two warrant officers and ninety-seven enlisted men. This provided a composite total of seven officers, two warrant officers, and one hundred seventy-two enlisted men.

b. Operational plans required the full time use of five officers, one warrant officer, and one hundred and fifty-three enlisted men in direct support of scheduled Research and Development projects. This left the commander, one officer, one warrant officer, and nineteen enlisted men to supervise the program, and to handle supply, mess, administration, and liaison activites. A command decision was made to provide the scheduled Research and Development projects with the maximum possible support. However, to do this, administration, property accounting, and housekeeping functions were neglected for the sake of operations.

c. Action has been initiated to correct the organizational deficiencies noted during the 1955 season by requesting additional officer and enlisted spaces which will permit the Task Force to organize along more practical and conventional lines.

2. Personnel:

a. The 1955 Task Force was composed largely of volunteer enlisted men. This policy not only permitted closer discrimination in selection of personnel but also assured a far higher level of performance than would otherwise have been possible. Volunteer personnel are considered highly desireable since the nature of the Greenland Research and Development Program requires that they be highly stable, dependable and able to work with a minimum amount of supervision.

b. Two seasons with the Task Force in Greenland is considered to be the most logical tour. Less than two years results in loss of continuity in key positions. This applies to both officers and first three grade enlisted men. More than two years would impose definite hardships on many of the soldiers concerned. This is particularly true of those who are married. Personnel should be assigned to the Task Force in such a manner that only fifty percent of the key personnel rotate during any single year. For example, the commander and the executive officer should not rotate on the same year.

c. Experience gained during the 1954-1955 seasons emphasizes the value of obtaining as many soldiers as possible who have been college trained in one of the professional fields, such as geology, civil, electrical, or mechanical engineering. Almost without exception these types of soldiers have been most valuable to project engineers since they can, without extensive training, do surveying, sketching, compile data, or install and operate scientific instruments.

3. Morale:

a. Morale of personnel in the Task Force was initially high and remained so during the entire season. This is considered to have stemmed from three factors. First, most personnel were carefully selected from among volunteers; second, all personnel were gainfully occupied with work which produced measurable and tangible results; third, all personnel were carefully indoctrinated with the importance of the Greenland Research and Development Program.

b. Only one psychoneurotic case developed during the 1955 season. In this instance alleged or imagined infidelity on the part of a spouse in the ZI was considered to have been the primary contributing cause. Closer screening prior to departure for Greenland could possibly have eliminated this case.

4. Discipline: A high standard of discipline was maintained in the Task Force throughout the season. In only one instance did a disciplinary infraction occur which necessitated action by courts-martial.

5. Administrative Channels: A directive from the Department of the Army appointed the commanding officer of the Transportation Arctic Group spokesman for both the 1st Engineer Arctic Task Force and the Transportation Arctic Group in all dealings with the Danish Liaison Officer and the Air Force. This was an unnecessary and time-consuming process which tended to compound confusion and did not work well in practice. By mutual consent, it was practically abandoned before the end of the season.

6. Housing Facilities:

a. The Task Force command and administrative sections were assigned three rooms in the Transportation Arctic Group Headquarters building, and one room in a barracks building shared by TRARG and the 1st EATF personnel. This arrangement led to needless confusion. Plans for 1956 provide that the Task Force operate a separate headquarters.

b. The bulk of the Task Force personnel lived at Camp TUTO where housing conditions were crowded but satisfactory.

7. Operation of Camp TUTO

a. Camp TUTO, the Engineer Base Camp in Greenland, was shared with the Transportation Arctic Group, whichoperated its special over-snow transport section from this location.

b. The camp was commanded by an officer from the 1st Engineer Arctic Task Force from April until September, at which time certain facilities were placed at the disposal of the Transportation Arctic Group for its winter operation.

c. The consolidated mess at Camp TUTO provided facilities for Transportation Corps, Engineer, and civilian personnel operating in the vicinity, and also served as a ration breakdown point for all sub-camp messes operating on the ice cap. The mess facilities were over-crowded and mess schedules were difficult to adjust, due to radical differences in the working hours and other administrative arrangements of the two services. Additional mess facilities have been constructed at Camp TUTO so that the over-crowded conditions will be alleviated during the summer of 1956.

1ST ENGINEER ARCTIC TASK FORCE
SECTION III

OPERATIONS

1. Planning:

a. Neither the Task Force nor any of the Research and Development agencies were able to do detailed operational planning until the program was officially approved and funds were made available. Since official approval was not obtained until January 1955, insufficient time was left to compute requirements, procure, and ship necessary supplies and equipment to Greenland prior to the start of the summer's work. This necessitated equipping the projects largely with supplies and equipment borrowed from the Transportation Arctic Group, The Area Engineer, or the Air Force. In many cases vitally essential items of equipment were not available at all, or were received only when the program was nearing its conclusion.

b. The Engineer program as originally planned was too ambitious in view of the time, shipping facilities, personnel and equipment available. Three optimistic assumptions were made in the original plans. First, that 215 instead of 181 military personnel would be authorized for the Greenland work; second, that necessary heavy engineer equipment could be obtained from the Area Engineer; third, that authorized T/A equipment, which had been requisitioned, would arrive in Greenland early enough to be used during the working season. All three of these assumptions were largely false and plans had to be revised accordingly. The scope of projects 1 and 3 had to be reduced by approximately fifty percent.

c. The lesson to be drawn from these experiences is that planning for any program which is to operate in an isolated region, located several thousand miles from its sources of supply, must be started sufficiently far in advance to permit realistic time schedules based upon firm shipping space allocations. If time does not permit such detailed planning, scheduling, and shipping arrangements, the scope of the program must be modified in accordance with supplies and equipment already on site. The Greenland program must be planned at least one year, and preferably two years in advance.

2. Scheduled Projects:

a. The 1955 Engineer Greenland program consisted of fourteen active projects as follows (For a detailed discussion, see Annexes A through N):

(1) Project 1 - Approach Road

(a) Consisted of constructing a road over ice using normal construction methods with random borrow and/or crushed stone. The original scope of this project contemplated extension of the ice cap road which had been started in 1954, to a point at or above the firn line, and also the construction of approximately one mile of road transverse to the drainage pattern. (Fig. 1)

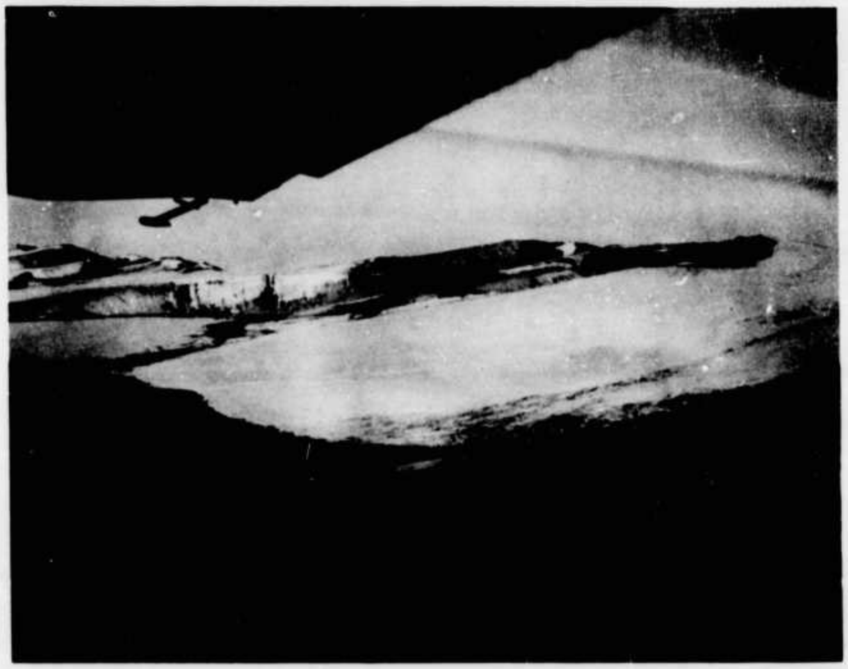


Fig. 1 Aerial View of Land-ice, Ramp Road and Moraine

(b) Approximately one mile of the 1954 construction had to be removed and reconstructed since the material which had been used contained too much fine silt which absorbed free moisture during the early melt season and as a result turned the road into a river of mud. (Fig. 2)

(c) Engineer earth moving equipment available in Greenland was not sufficient to accomplish the amount of work originally planned. Consequently the scope of the project had to be modified. The modified plan, which included all of the proposed tests on a reduced scale, was accomplished. That portion of 1954 construction which failed was replaced and approximately two miles of new road was constructed, including one eighth mile of road transverse to the drainage pattern.

Fig. 2 Fill Material Used in Rebuilding Washed Out Section of 1954 Constructed Ramp Road

(2) Project 2 - Transfer Point

(a) Consisted of the construction of a transfer point at the end of the approach road which would provide working space to transfer cargo from trucks to sleds.

(b) A transfer point, eighty feet in diameter, was constructed at the end of the ice cap road. Random borrow and and crushed stone was used for this construction.

(3) Project 3 - Snow Compaction

(a) Original plans for this project contemplated compaction of two operational snow runways capable of sustaining wheel landing of heavy transport aircraft including C-54 and C-124 type planes. The first runway was scheduled to be constructed at a site 220 miles from Thule and at an elevation of approximately 7000 feet; the second runway was scheduled to be constructed at a site approximately 385 miles from Thule and at an elevation of 9000 feet.

(b) It was readily apparent even before the project was started that neither sufficient equipment nor personnel were available to complete two runways during the short arctic working season. Consequently plans for compacting a second runway were cancelled, and the entire available effort was concentrated on compacting the first runway.

(c) Considerable difficulties were experienced in maintaining pulvimixers and low ground pressure D-8 tractors due to a lack of sufficient spare parts and an acute shortage of qualified maintenace personnel. This situation was further aggravated by a lack of sufficient low ground pressure tractors to permit snow compaction equipment to be used in the most efficient manner. (Fig. 3)

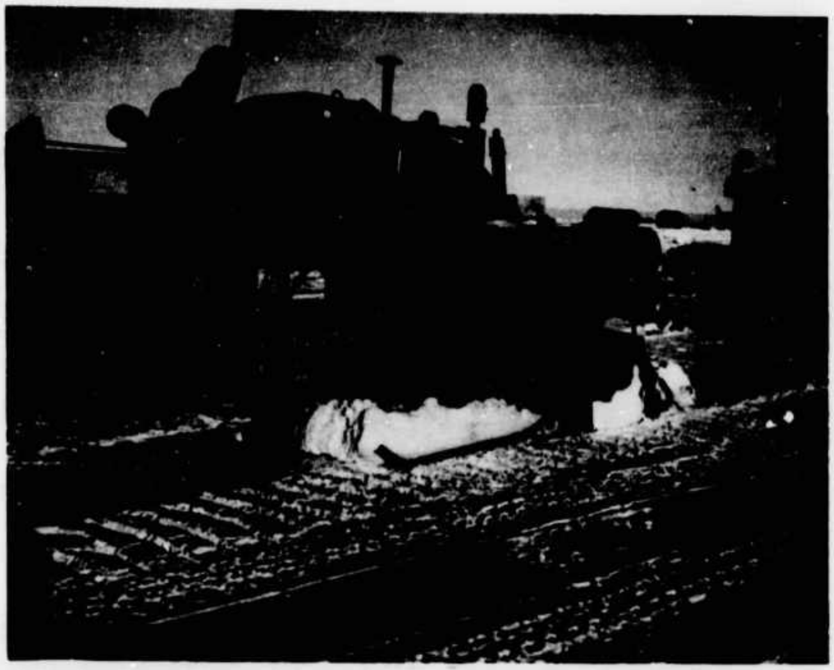


Fig. 3 Pulvimixer and Operator

(d) Despite maintenace difficulties, shortage of personnel and equipment, compaction of the first strip was completed on or about the 20th of September, and although densities and hardness achieved were not uniform throughout the entire 10,000 foot length of the strip, the project engineer considered it ready for operational testing of wheel-type aircraft. (Figs. 4 and 5)

(e) Testing of the strip was conducted during the period 21 through 28 September. More than sixteen separate landings were made on the strip during this period as follows:

Type Aircraft	Number of Landings	Dates
C-47	8	9 - 28 September
C-54	6	10 - 25 September
C-124	7	25 - 28 September

Fig. 4 Rear View of D-7, LGP, pulling Drag Unit and Corrugated Steel Roller

Fig. 5 Rotor Unit of Pulvimixer Showing Track in Snow Surface

(f) The C-124 landings were made with increasingly heavier loads until indications of failure occurred. The last two landings were made with an initial gross load of 168,000 pounds. Considerable rutting occurred during all of the C-124 tests, but this was due primarily to a surface layer of unprocessed snow which had fallen after the next processing had been completed. On the last day of the test landings, failures occurred in two places. In each case these failures consisted of complete disaggregation of the processed layer. Both failures are considered to have resulted from two factors, the reversing of the C-124 propellers, and the method which was used to compact the strip. The strip was compacted in segments of 2500 feet each. The failure in each case coincided with the equipment turn-around areas at the ends of the segments. (Figs. 6 and 7)

Fig. 6 C-47 Making Wheeled Landing on Compacted Runway

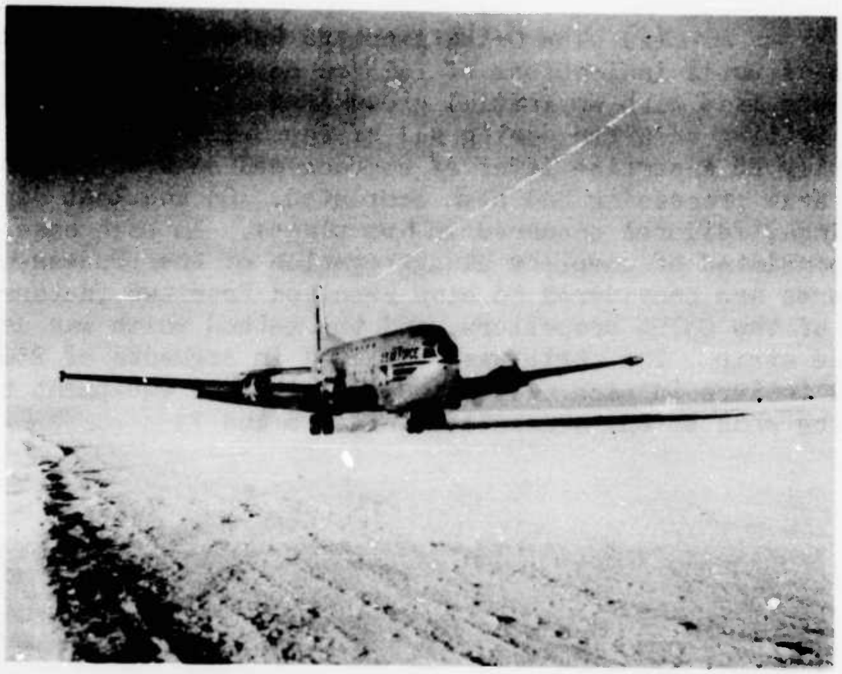


Fig. 7 C-124 Taking Off From Snow Compacted Air Strip

(4) <u>Project 5 - Basic Crevasse Studies</u>

(a) Consisted of studies to determine the nature, movements, and characteristic behavior of crevasses on the Greenland Ice Cap. The project was divided into two parts. Part 1 was devoted to a detailed study of specific crevasses in Blue Ice Valley. Part 2 was devoted to a general statistical survey and description of sampled crevasses, and an attempt to relate the information obtained to Part 1 of this project. Part 2 also consisted of the preparation of a crevasse map of the area between Thule Take-Off and Point Alpha based on photo interpretation and field reconnaissance. (Figs. 8 and 9)

(b) Considerable difficulty was experienced in equipping this project since many small items of equipment had to be obtained from the Transportation Arctic Group and most items in question, such as radios, stoves, barrel pumps, mess trays, etc. were not available from any source in sufficient quantities to satisfy fully project requirements.

(c) Excellent progress was made by project personnel after the project was once under way. Weather conditions did, however, hamper survey and reconnaissance work from time to time throughout the season.

(d) Project objectives in general were realized with the exception of a photo mapping mission which was arranged, but could not be accomplished because of poor weather and visibility conditions during the period in which the photo mapping crew was available in Thule.

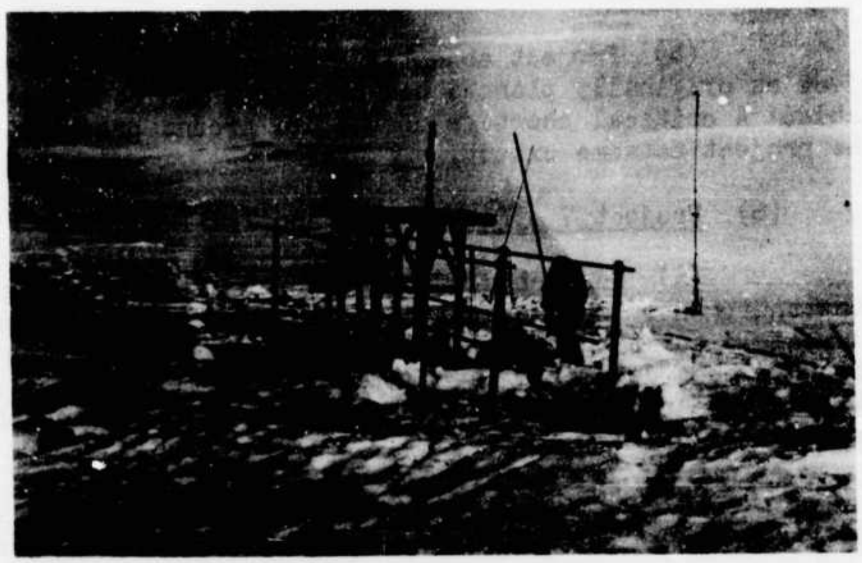


Fig. 8 Bridgework Erected Across Crevasse to Facilitate Entrance and Exit

Fig. 9 View of Crevasse Immediately Under Snow Bridge

(5) Project 6 - Trafficability

(a) Consisted of a mobile swing of rubber-tired and tracked vehicles over the ice cap in order to examine performance characteristics under varied snow conditions. This swing was accomplished during July and August.

(b) Project objectives were realized but the scope of the project as originally planned had to be reduced to fit the equipment available. A critical shortage of D-8 low ground pressure tractors hampered the project to some extent.

(6) Project 7 - Pathfinding and Trail Marking

(a) Consisted of the testing of pathfinding and trail marking equipment. The equipment tested consisted of a gyrocompass and vehicle position indicator, and a wire trail marking system, which had been developed in rudimentary form during the summer of 1954. Vehicular radar equipment was also tested during the course of the summer's work.

(b) Very little difficulty was experienced and project objectives were fully realized before the end of the season. (Fig. 10)

Fig. 10 Arma Gyrocompass for Combat Vehicles Mounted On a Vehicle

(7) Project 8 - Crevasse Detection

(a) Consisted of continued investigation of possible electronic means of detecting hidden crevasses.

(b) A low frequency, continuous flow net detector was fabricated and tested. It showed promising results from the first day by giving positive indications each time it passed over known crevasses. Although it also registered miscellaneous anomolies in the snow and ice, the order of amplitude when over a crevasse was such that a mistake in interpreting the signal was highly improbable.

(c) Equipment utilizing the radar principle was also given some preliminary testing, but results were inconclusive and not encouraging.

(8) Project 10 - Ramp Studies

(a) Consisted of a continuation of the observations started in 1954 of ramp movements and behavior.

(b) Two sets of observations were completed during the year. One was made early in March and the other was completed during the summer.

(9) Project 12 - Surface Snow Studies

(a) Consisted of studies in surface snow conditions, trailmarking, and the logistics of ice cap travel by light swings.

(b) A light swing of approximately 1200 miles was made over the central Greenland ice cap. Resupply was accomplished by air drop. Both free fall and parachute drops were made. Vehicles and equipment were cached and the personnel were evacuated by air at the end of the season. Much data was collected and when correlated and evaluated should provide a wealth of valuable information.

(10) Project 13 - Snow Structures

(a) A series of cut and cover trenches were constructed and observations of the tunnel and pit constructed in 1954 were continued.

(b) A snow milling machine imported from Switzerland was used for trenching operations and proved to be highly efficient for this type of work. Several methods were improvised to cover the trenches constructed. See Annex for a detailed discussion of methods used.

(c) The tunnel and pit constructed and instrumented in 1954 were observed to measure deformation, loads and stresses. (Figs. 11, 12 and 13)

Fig. 11 Peter Senior Blowing Snow on Plywood Arches

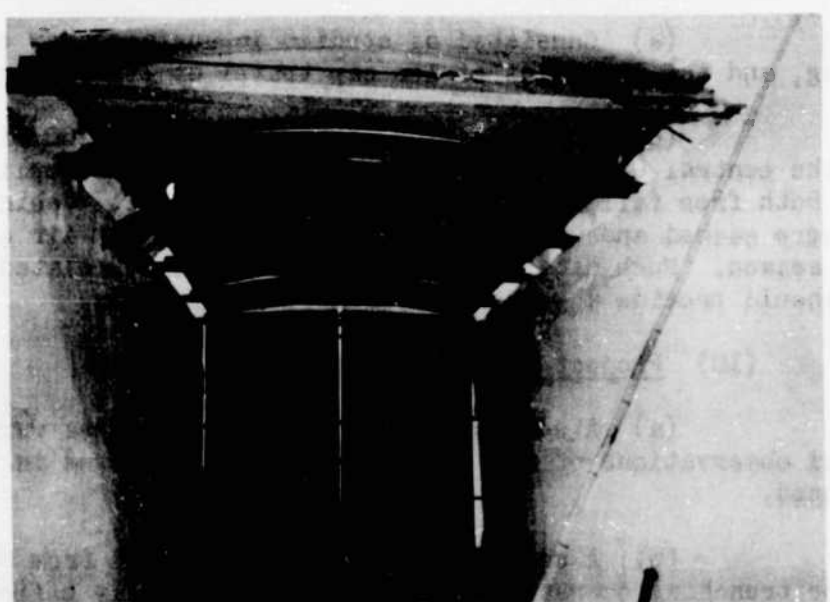


Fig. 12 Bottom View of Arched Plywood Panels Used To Cover Eight Foot Trench

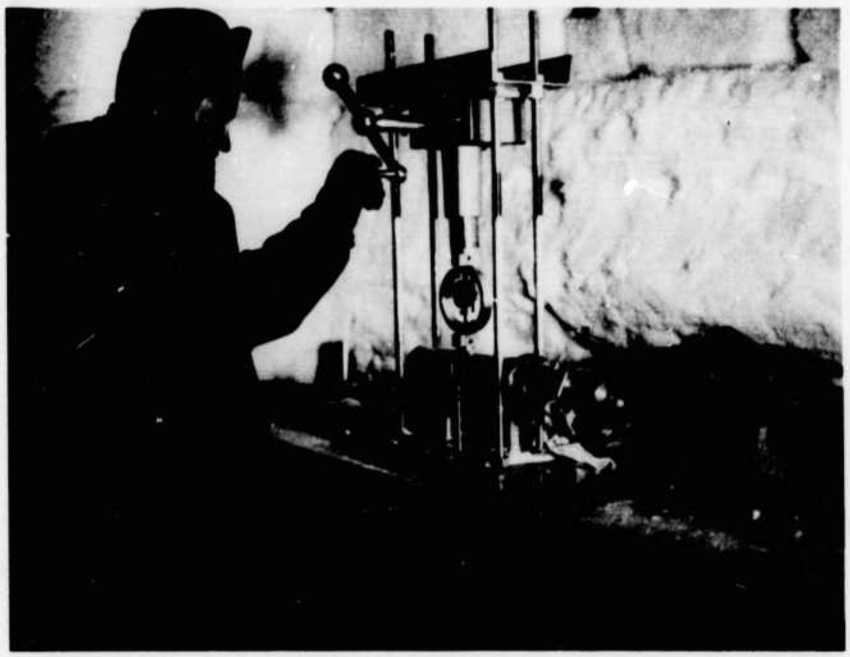


Fig. 13 Stress-Strain Gauge in Underground "Snow Lab"

(11) Project 18 - Permafrost and Pattern Ground Studies

(a) Consisted of studies in permafrost and pattern ground, including the size, shape, and composition of patterns and the relationship of other geologic and topographic features to their presence.

(b) Project objectives as outlined in the original program were achieved. The project was hampered to some extent, however, by lack of the full time use of an angle dozer. (Figs. 14, 15, and 16)

Fig. 14 Small Mammamate Soil Forms Occurring on a Side Hill

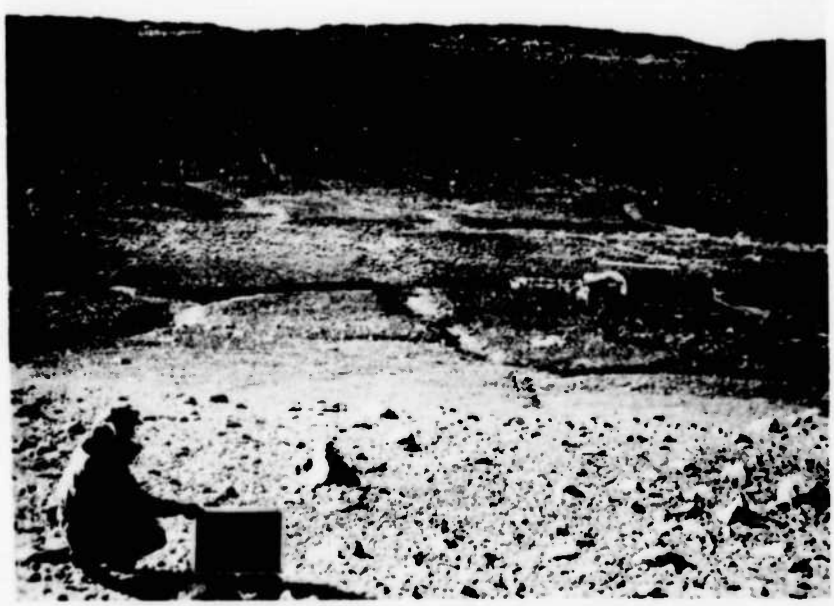


Fig. 15 Large Frost Patterns Formed in Gentle Shallow Valley

Fig. 16 Striped Ground Found on Moderate Slope

(12) Project 22 - Ice Tunnel

(a) Consisted of the excavation of a 500 foot tunnel in glacial ice to study tunneling techniques and the characteristic behavior of unsupported ice arches, corners, and fillets. (Fig. 17)

Fig. 17 Rear Wall of Jamesway Size Room Cut for NEAC

(b) All excavation was accomplished with hand tools only. Work progressed at the rate of 8 to 10 feet per day. The tunnel was instrumented as soon as completed in order to measure deformation, temperatures, and differential movement of shear planes.

Fig. 18 Dumping Sled Load of Ice dug from TUTO Tunnel

(13) Project 23 - Snow Drift and Whiteout Studies

(a) Consisted of a study in the dynamics of drifting snow with a view toward development of control measures. It also included studies in visibility during whiteouts.

(b) One snow fence was constructed of lumber and another was build of snow blocks. The snow drift patterns resulting from each type of fence were carefully observed. Whiteout conditions experienced at Fist Clench were studied throughout the season. (Figs. 19 and 20)

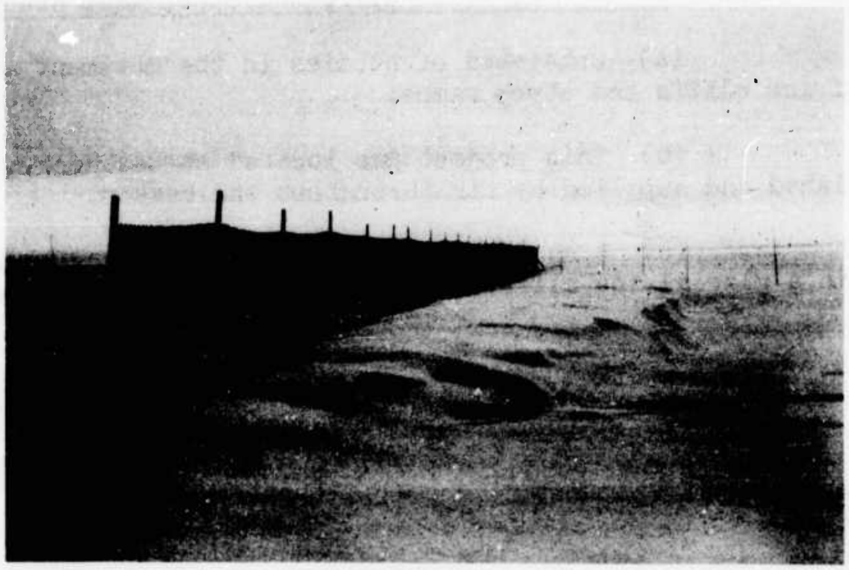


Fig 19 Double Tiered Snow Fence Erected to Study Snow Drift

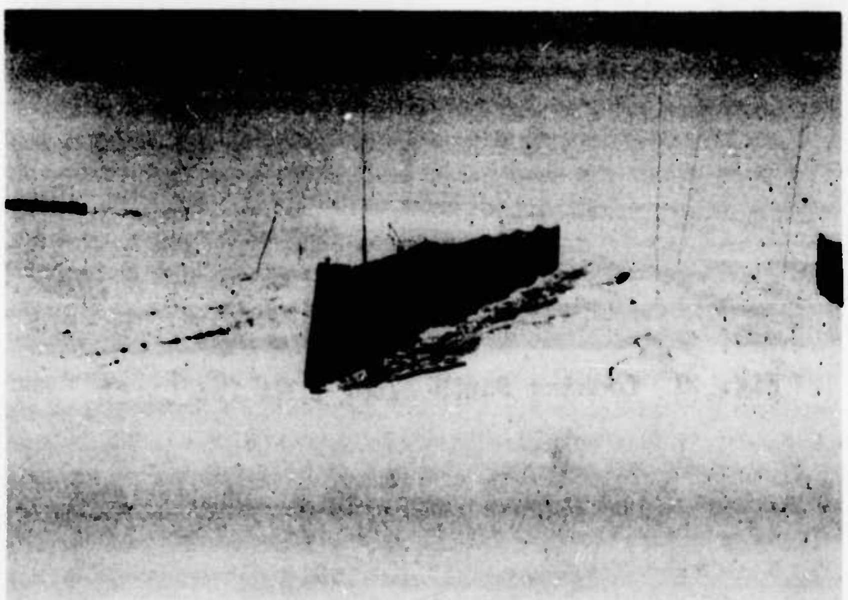


Fig. 20 One of Paired Fences used to Direct Drifting

(14) <u>Project 24 - Ice Cliff and Steep Ramp Studies</u>

(a) Consisted of studies in the movement and general behavior of ice cliffs and steep ramps.

(b) This project was located at Red Rock. The camp was established and supplied by air throughout the season.

(c) A short tunnel for investigational purposes was excavated in a glacial ice cliff. Project objectives were achieved.

Fig. 21 Looking South Along NUNA Ice Cliff

3. Additional Projects

a. Construction of a Semi-Permanent Camp at TUTO

(1) An agreement was made with the Transportation Arctic Group to attempt the construction of a semi-permanent camp at Thule Take-Off. This camp was to consist of:

Type Building	Number each	Purpose
Quonset	20	Living Quarters
Prefabricated (Modular type)	3	Mess Hall, Kitchen, Maintenance Shop
Wooden Frame	1	Shower and Ablution Building

(2) The Transportation Arctic Group provided the unskilled labor required for the project. Supervision, equipment, building materials, and skilled workmen were provided by the Corps of Engineers. Construction of the camp was completed on 20 September. (Figs. 22 and 23)

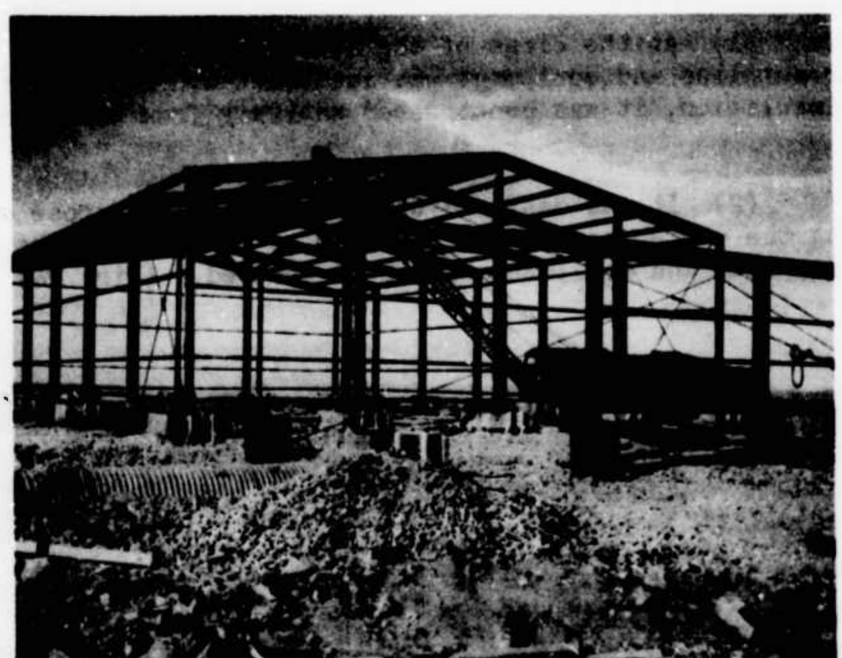


Fig. 22 Frame of Modular Building Erected for Mess Hall and Kitchen

Fig. 23 Aerial View of Completed Camp Seen From The East

b. Warehouse

(1) At the close of the season a warehouse for storage of engineer supplies and equipment was constructed. Except for roofing paper and insulation, it was constructed entirely from scrap and salvaged materials.

(2) It was designed to serve the dual purpose of a warehouse during the winter and a kitchen and mess hall during the summer after the supplies and equipment have been removed. (Fig. 24)

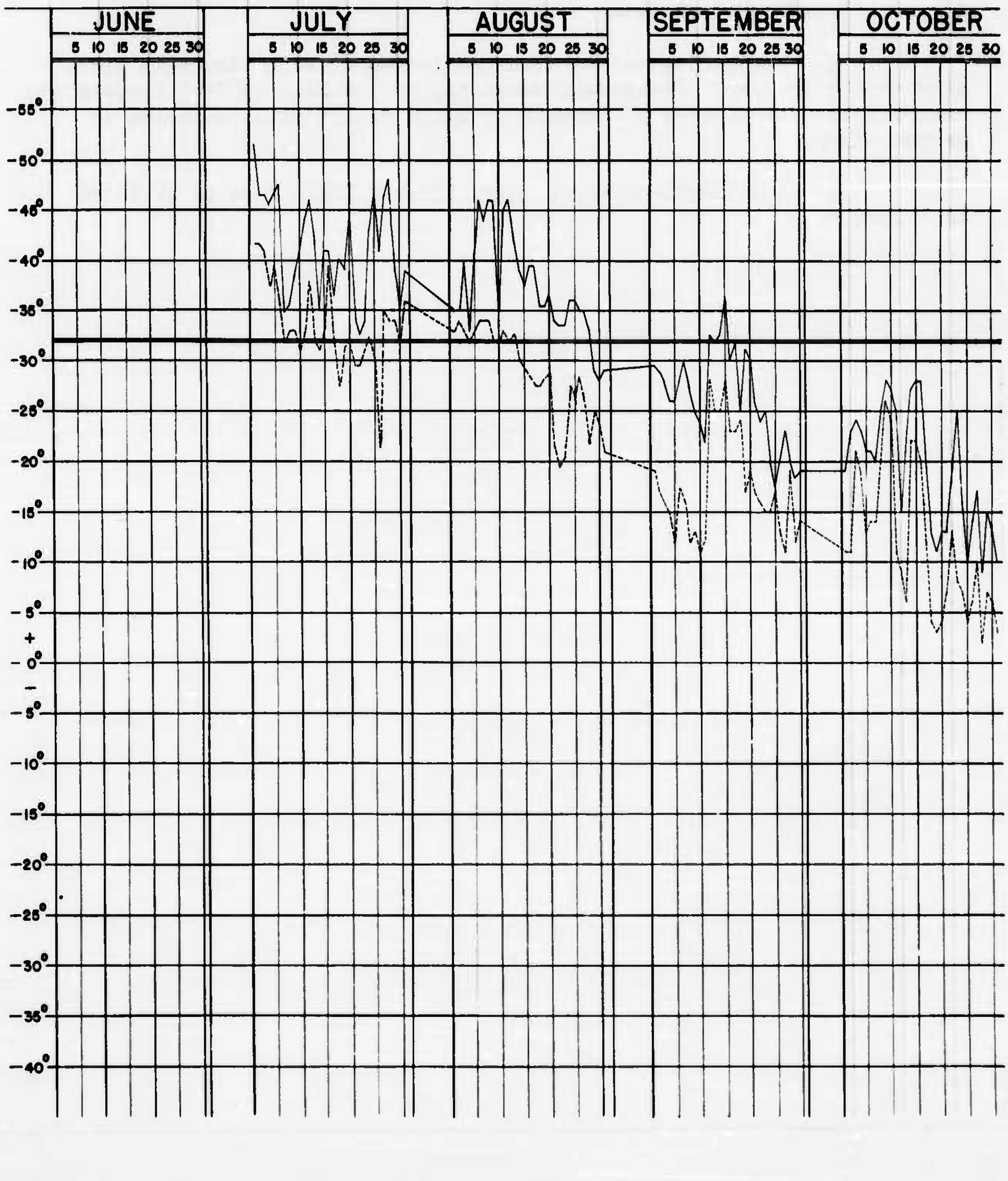
Fig. 24 Completed Kitchen-Warehouse at Engineer Camp TUTO

4. Meteorological Data

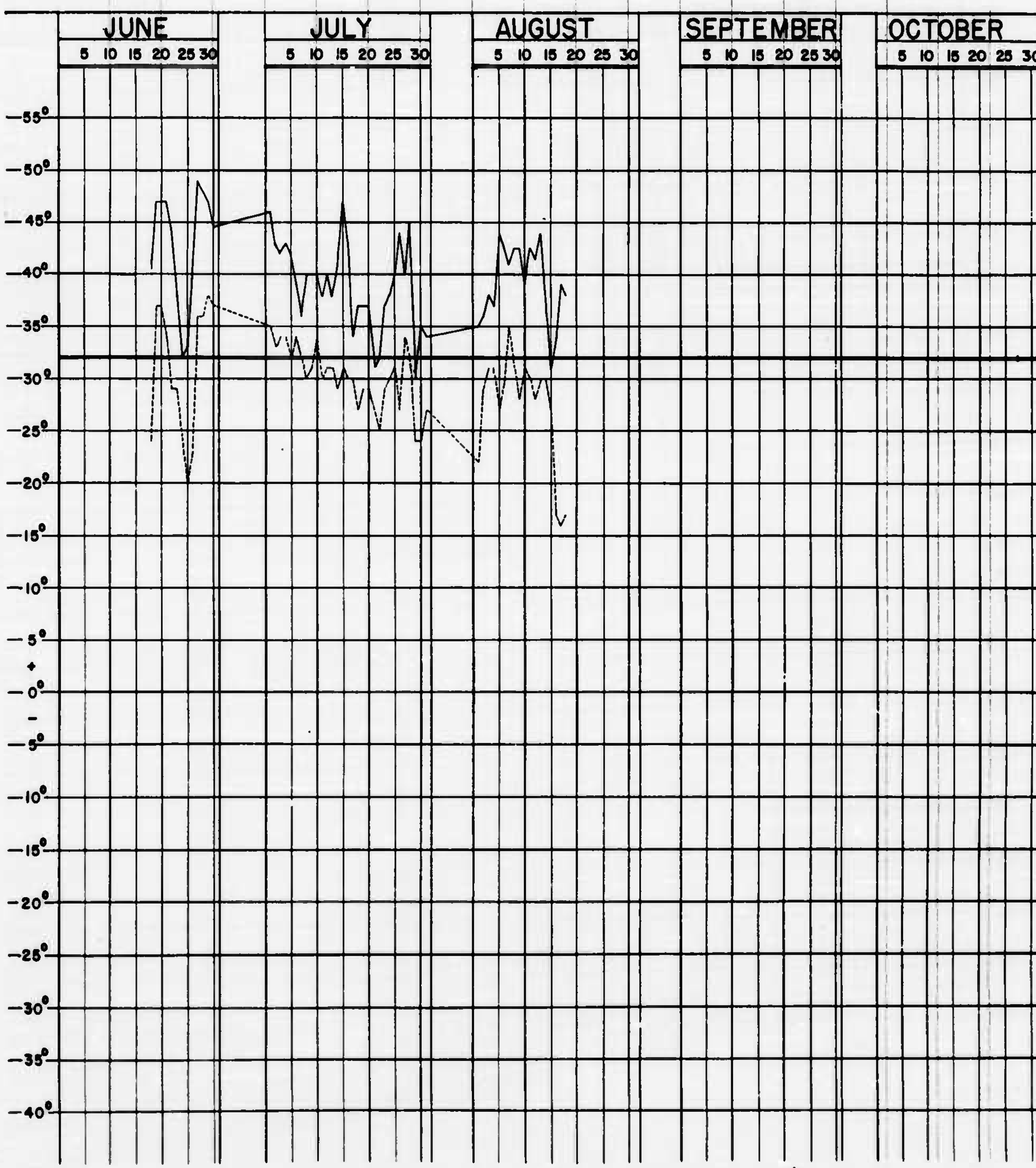
a. Meteorological data was collected at each camp site operated on the ice cap. These data consisted of low-high ambient temperature recordings. See figures 25 through 29 which depict data collected in graphic form.

b. A daylight-darkness chart for the Thule area is included as Figure 30.

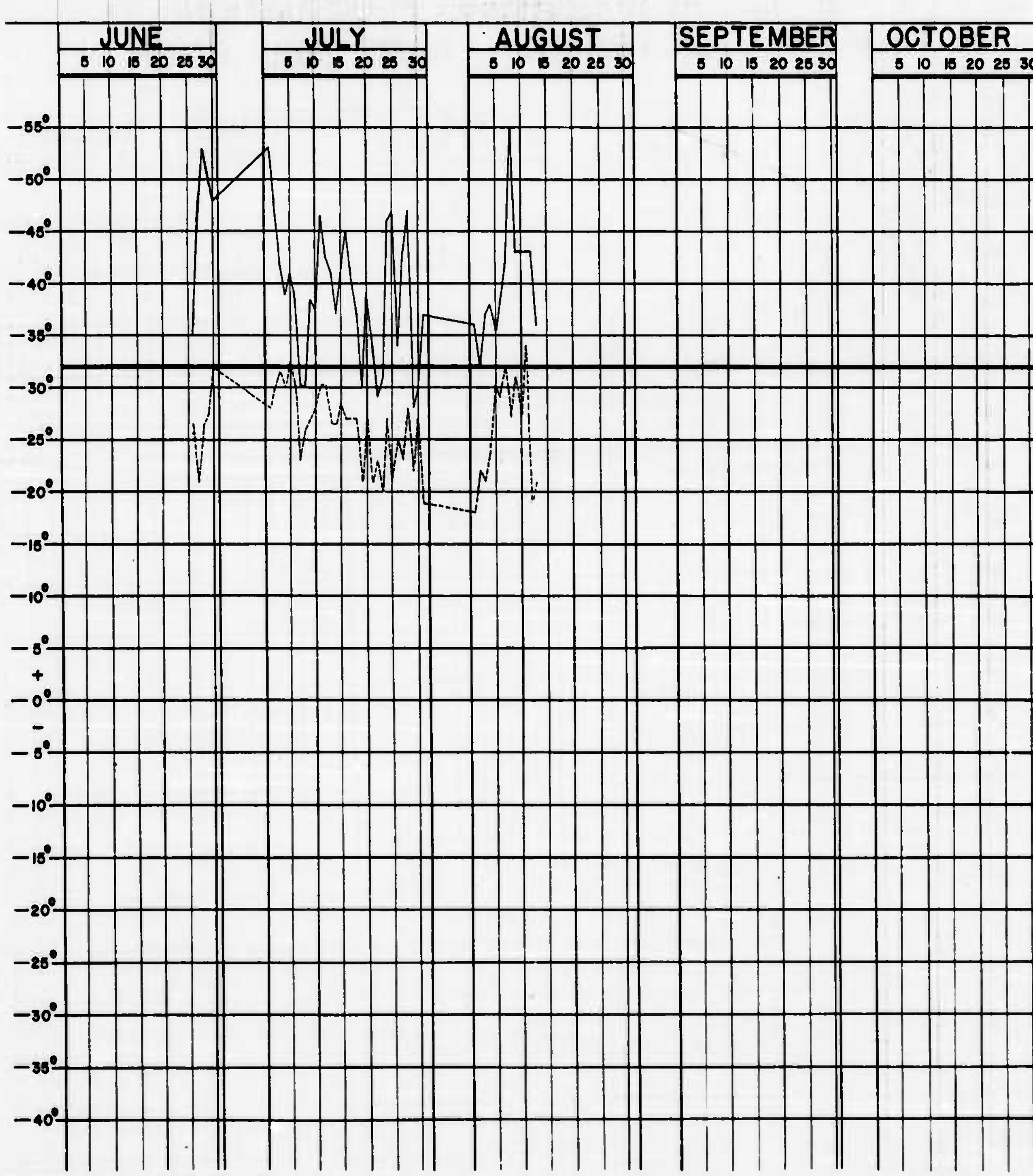
HI-LO TEMPERATURE FLUCTUATION FOR 24 HOUR PERIOD — CAMP TUTO



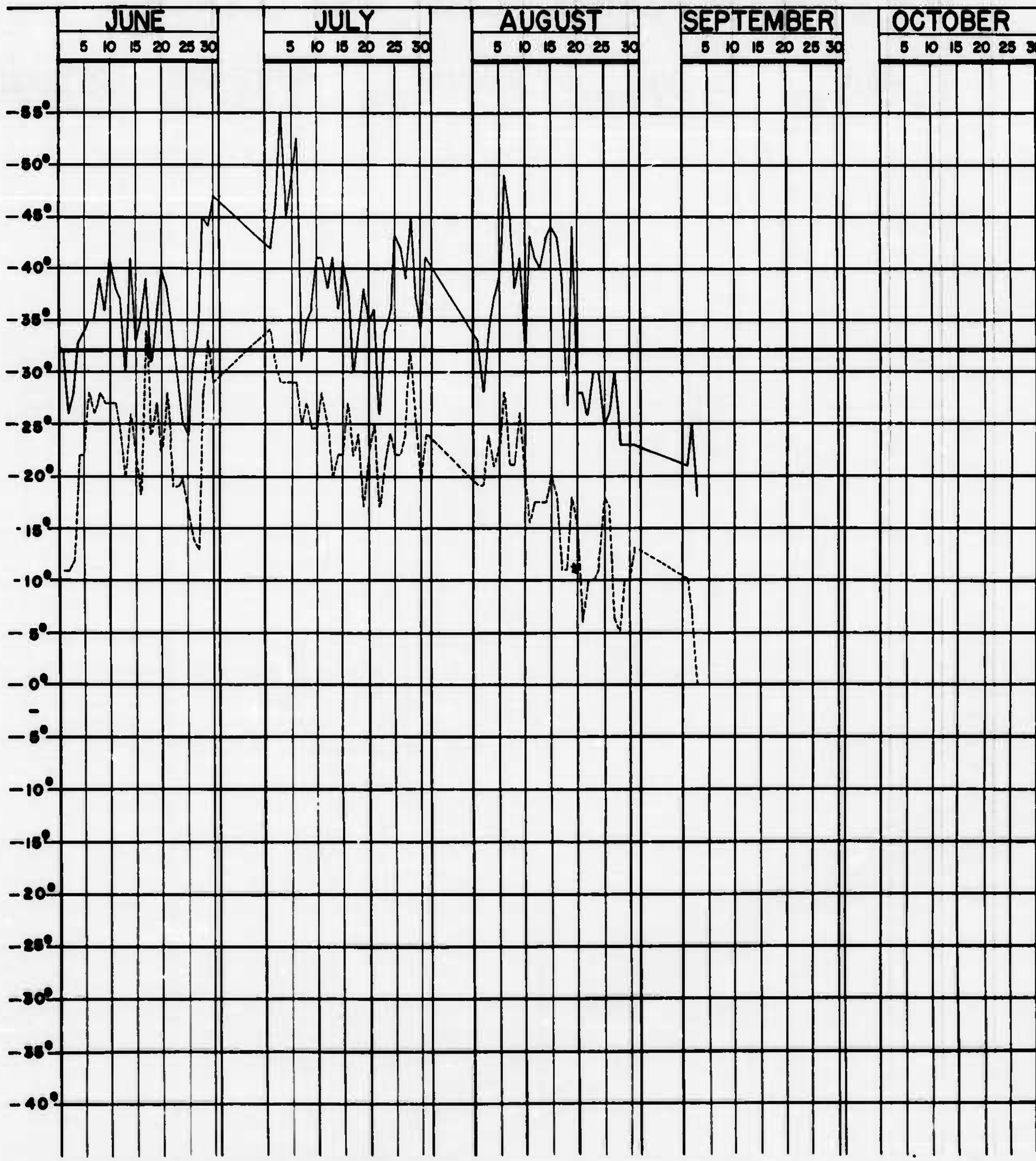
HI - LO TEMPERATURE FLUCTUATION FOR 24 HOUR PERIOD - CAMP RED ROCK



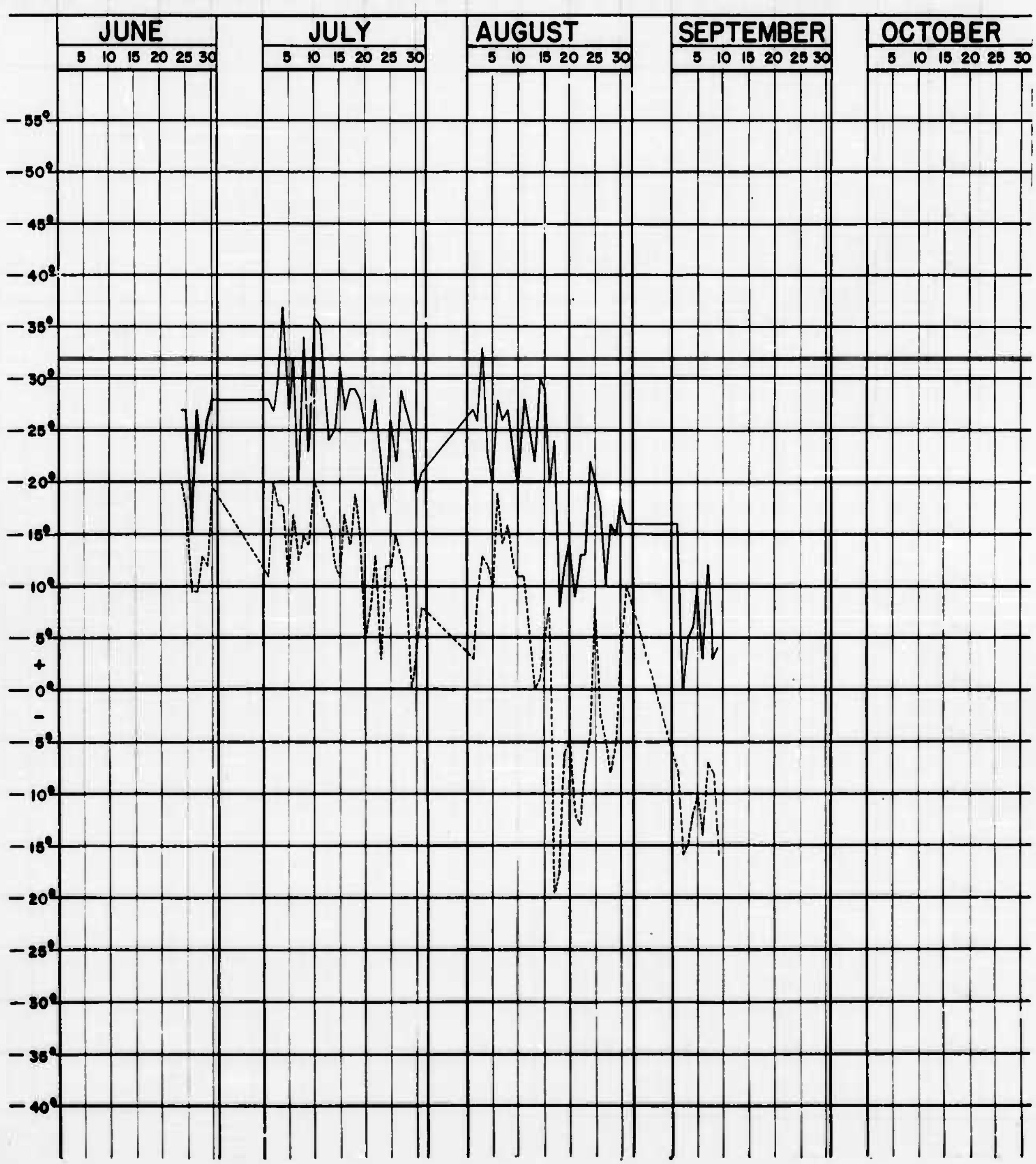
HI - LO TEMPERATURE FLUCTUATION FOR 24 HOUR PERIOD - BLUE ICE VALLEY



HI - LO TEMPERATURE FLUCTUATION FOR 24 HOUR PERIOD - CAMP WHITEHORSE

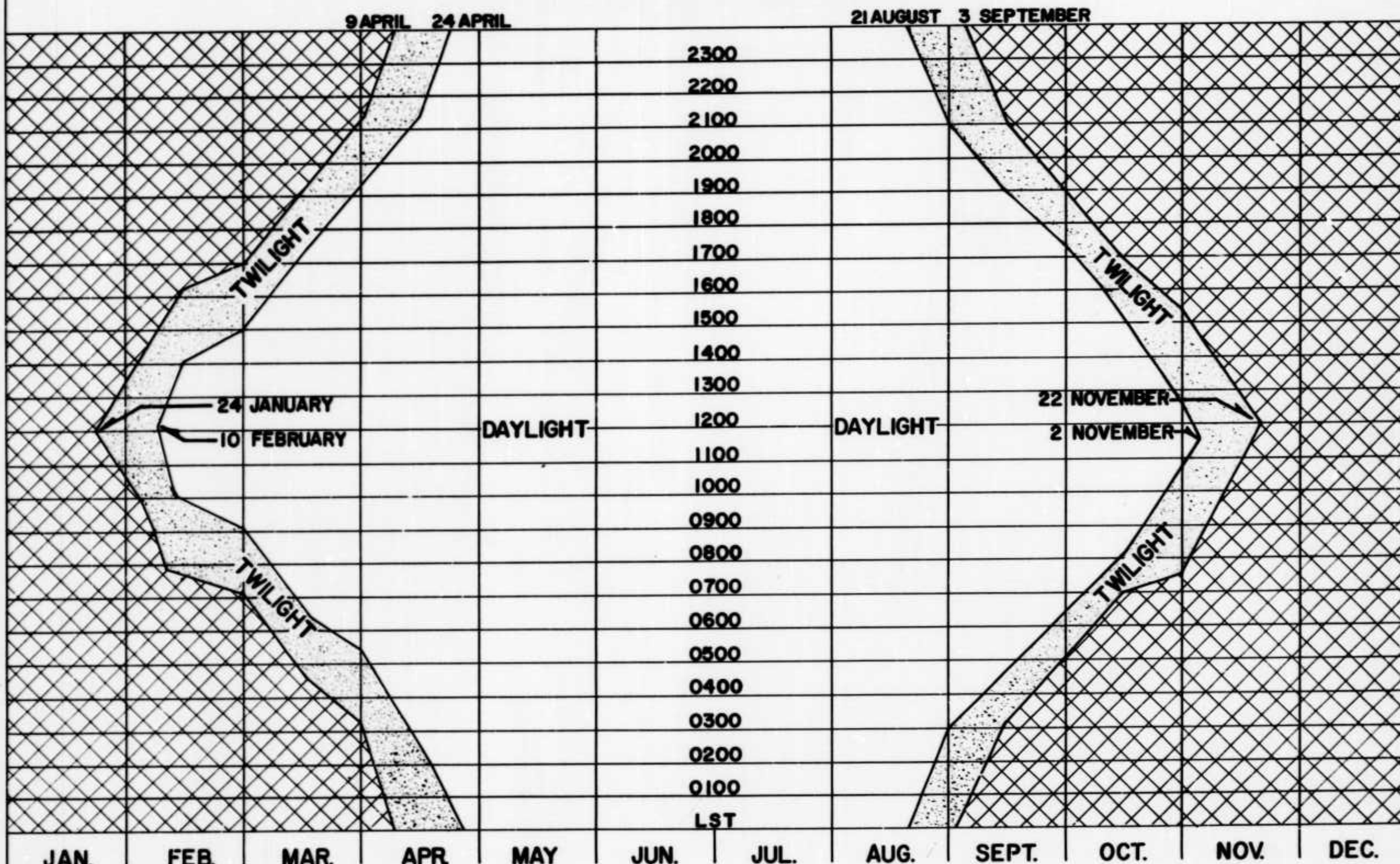


HI-LO TEMPERATURE FLUCTUATION
FOR 24 HOUR PERIOD - CAMP FIST CLENCH



DAYLIGHT-DARKNESS CHART

CAMP TUTO, GREENLAND



1ST ENGINEER ARCTIC TASK FORCE
SUPPLY
SECTION IV

1. Planning

a. Due to late approval of the 1955 Greenland program, planning for logistical support of the scheduled projects was, of necessity, accomplished in a hasty, piece-meal fashion. Most items which were requisitioned did not arrive in Greenland early enough to be used to equip the projects. As a result, they had to be equipped with items borrowed from the Area Engineer, The Air Force, or the Transportation Arctic Group. This resulted in unavoidable delays, dissatisfaction on the part of project engineers and a serious loss of valuable working days by project personnel. No single project was or could be provided all items of equipment which sponsering agencies had requested.

b. This situation can never be completely remedied, but it can be reduced to unimportant proportions if a firm program can be finalized and approved at least one year in advance of the implementation date. This will provide sufficient time to plan logistical support carefully, and to procure and ship the necessary supplies and equipment to Greenland well in advance of the starting date of the summer working season.

2. Records

a. Supply and property records which had been prepared by the Task Force in 1954 were incomplete, and in many cases inaccurate. Much effort was devoted by supply personnel during the 1955 season to correct this situation.

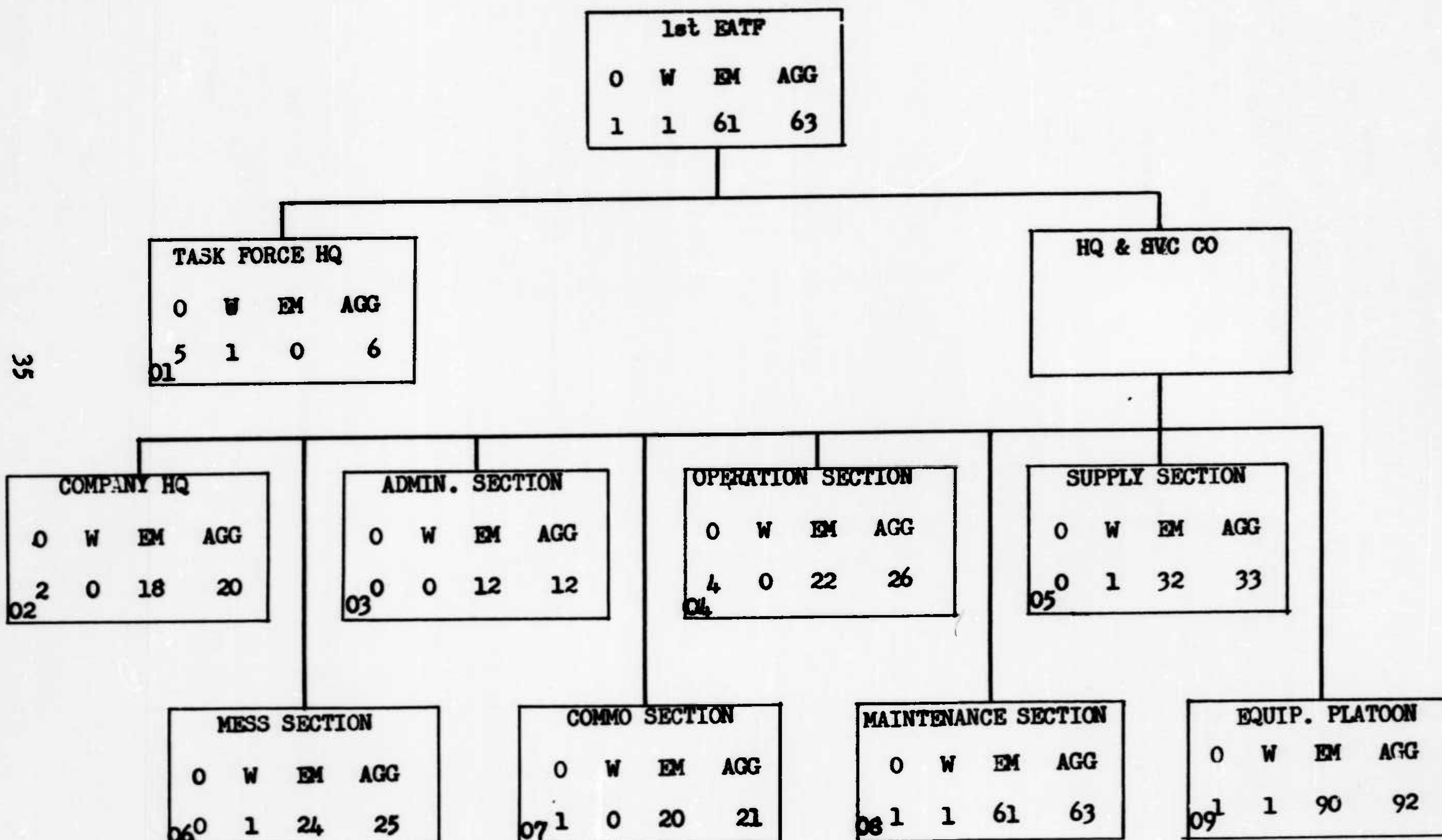
b. The Task Force was designated as the responsible agency for all equipment shipped to Greenland belonging to ERDL, SIPRE, WES, or ACFEL. As a result, a separate set of property records were maintained for each agency as well as for the Task Force. This situation was further complicated by the fact that the Task Force was comprised of two seperate units, a TD unit and a TO&E unit, which again necessitated that seperate sets of property records be kept for each of the two military units.

3. Corrective Action:

a. To provide a well balanced military unit capable of providing required logistical support for the Greenland program, a proposed T/D & T/A were prepared and submitted for approval. The T/D included 14 officers, 5 warrent officers, and 279 enlisted men, organized as shown by figure 31. The T/A included all standard military items of equipment required for support of the Greenland program. It was based upon two years of actual experience in Greenland and upon carefully tabulated requirements for the 1956 program as known at the time of preparation.

b. The nature of the Greenland Research and Development program is such that in all probability, the T/A will have to be revised annually to reflect current requirements for project support, but since it normally requires from six months to a year to obtain final approval of a new or revised T/A, the Task Force will constantly have items of equipment on hand which are in excess to those authorized by the approved T/A.

T/D ORGANIZATION
1st ENGINEER ARCTIC TASK FORCE



SECTION V
PROJECT REPORTS
Annex A through N

Annex A

PRELIMINARY REPORT
Project 1 (Approach Road)

PROJECT ENGINEER: William F. Brace

1. Summary of Accomplishments

a. Much of the work and data collected during this summer cannot be analysed in the time remaining us in the field. This includes the thermal data, meteorological observations, and portions of the soils data and road movement survey. A more complete report of Greenland activities during 1955 will be available this coming winter.

b. The main road on the icecap was constructed as far as possible in the time available, 21 June to 27 August 1955. The tests called for were carried out and test sections constructed with minor modifications. Many of the experimental sections can only be evaluated following the thawing season of 1956. Conclusions regarding these sections as given here should be regarded as tentative.

(1) Equipment used. The following heavy equipment was made available to Project 1:

Operating Equipment	Standby Equipment
4 Mack Trucks, 10 yd	1 D-7
3 D-8's	1 Rock Crusher, 25 cu yd
1 3/4 yd. crawler type shovel*	3 Scrapers
1 3/4 yd. truck mounted shovel	2 Galion Rollers
2 2½ ton dump trucks	
1 Motor Grader	

* NOTE: This shovel operated 2½ days before breakdown.

(2) Volume-footage-time study of road construction

	Road Rebuilding	Transverse Road	Main Road	Total
Station:	31-47+00	0-8+00	47-93+00	
Lineal Feet:	1600	800 (640)	4600	6840
Time:	20/6-13/7	12/7-22/7	24/7-20/8	
Shifts:	20	10	47	77

	Road Rebuilding	Transverse Road	Main Road	Total
Yds Placed:	5150	3150	14960	23260
Lin. Ft/Shift:	80	65	98	81
Cu. yds/Shift:	310	310	318	313
Available Equipment hours:	2050	1116	4800	7966
Operating:	46.5%	49%	52%	51.7%
Deadlined:	34.5%	19%	6%	15.1%
Standby: (No operator or loaned)	28.5%	33%	42%	33.2%

Notes on above figures

(a) The main ice cap road had been constructed during 1954, as far as station 47+00. By the middle of June of this season, however, a large portion of this proved untrafficable 1600 feet of road was removed down to the ice subgrade and new fill placed on the old centerline.

(b) Distance of road refers to standard cross-section of 30 foot roadway, 1:1 slopes and minimum 2½ foot thickness with 6" crown. The transverse road was build 24 feet wide and 3 feet minimum thickness. Distance is expressed above in terms of standard roadway.

(c) Prior to 20 July, Project 1 operated one shift of about nine working hours. After 20 July, two shifts operated with about 8½ hours per shift.

(d) Yardage is figured on the basis of estimated yards per truck.

(e) Deadline hours include only those hours of repair during the standard work week; it does not include regular maintenance periods.

(f) Standby hours reflect, (1) the lack of operators for certain equipment, and (2) the unsuitability, or lack of need of certain equipment, such as scrapers, D-7 tractor, and a second 2½ ton dump truck.

(g) The increasing production per shift reflects the increasing skill of the operators through the summer in spite of the increased haul distances. Low output in building the transverse road was due to time spent in constructing culverts and drains. In the main road even higher output might have been realized had it not been necessary to construct numerous test fill sections and the instrumented Test Land Five.

(3) Test Fills used

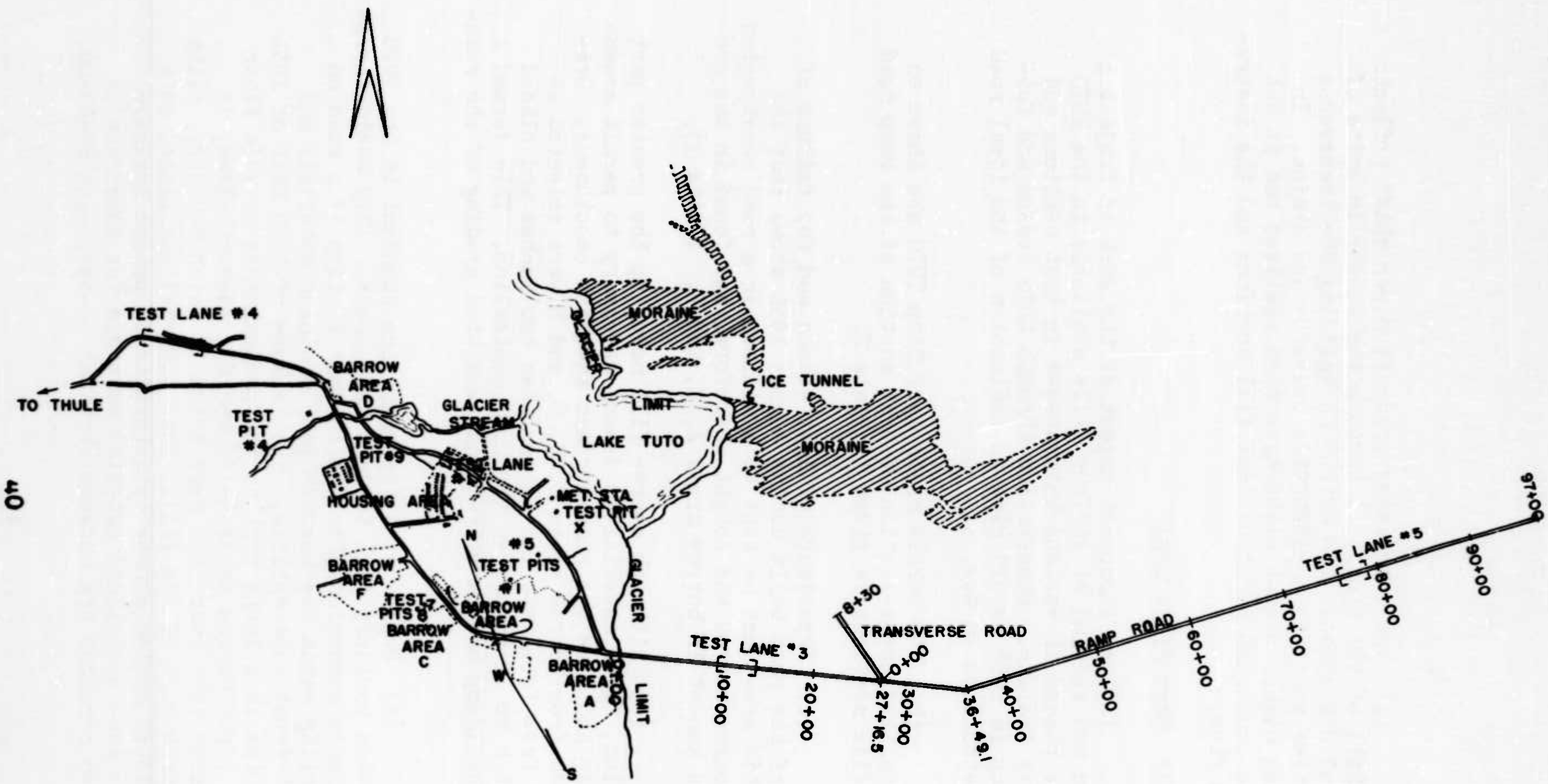
(a) An important aspect of the work of Project 1 was the selection and testing of various fills available in the TUTO area. These were placed in various thicknesses in test sections and subjected to heavy traffic. Observation through this season and following the thawing in 1956 should give an indication of the ideal road material for construction on ice.

(b) The borrow areas near Camp TUTO are shown on Plate 1. A generalized cross-section of that section of the ramp road containing test fill sections is given in Plate 2.

(c) Experience of last season and the failure of a large portion of the road built during August 1954 shows that the silty sands of this area must be kept to a minimum in a road constructed on ice. Clean coarse borrow was sought therefore, and found in the proper condition and amount in borrow areas A, E, and F. (Plate 1).

(d) Although coarse fill makes up the greater part of the road section, finer material is deemed necessary to permit crowning of the roadway and give the road surface adequate smoothness. Gravelly, silty sands from borrow areas C, D, G, and H were selected as being relatively free from material larger than two inches and placed at a thickness of 6 to 12 inches at the road centerline. This formed a topping for the bouldery bottom course and permitted grading of the roadway.

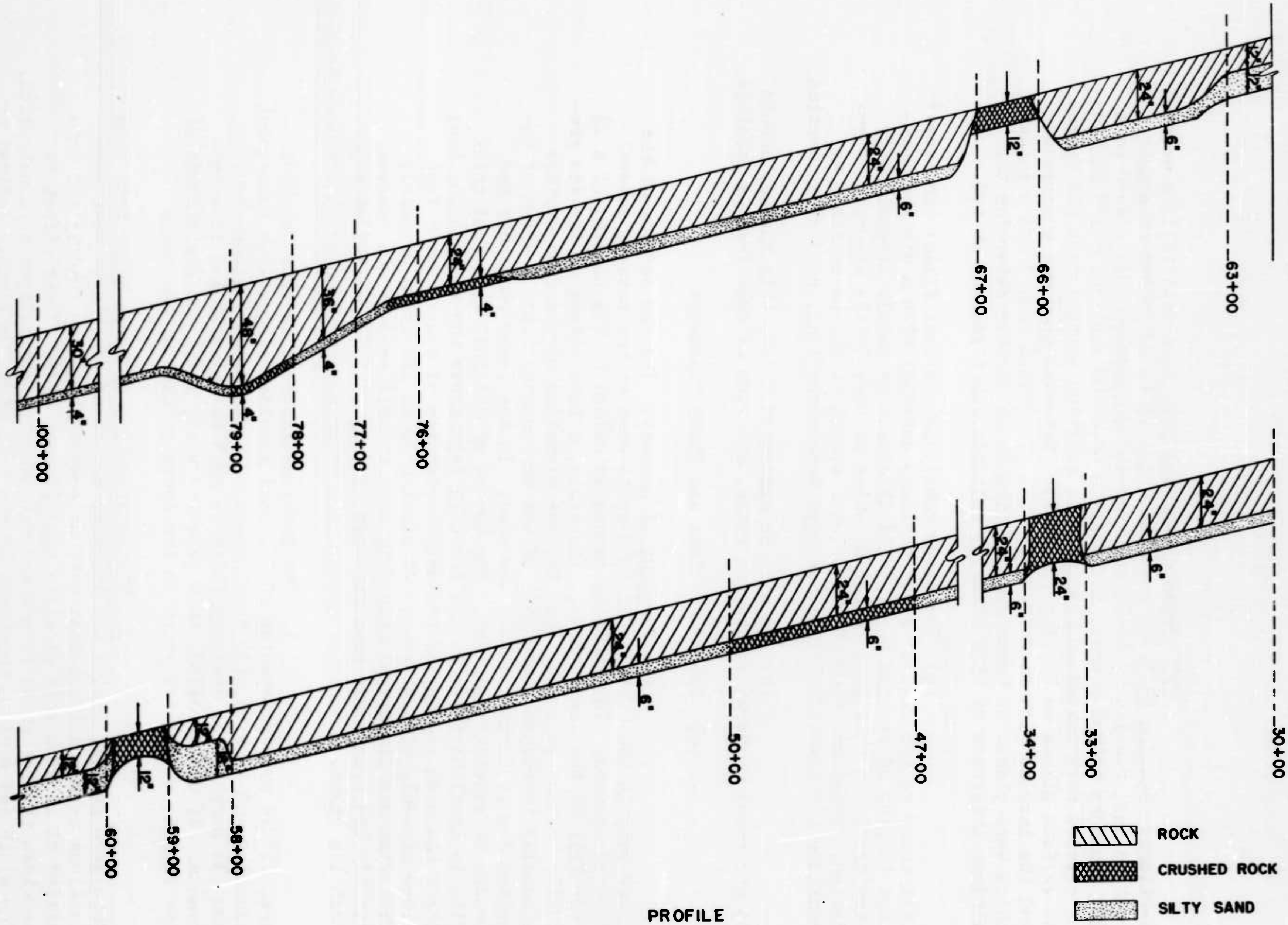
(e) Bouldery, silty sands are abundant in the TUTO area and easier than bouldery fill to load and spread. They would therefore be somewhat more economical for use in construction of a road on ice. Bouldery, silty sands are however poor draining materials and probably somewhat frost subsceptible. The failure of 1600 feet of 1954 road is probably due in a large part to the predominance of this finer grained material (from borrow areas A-'54 and B). Nevertheless, in test sections placed this year, two were tried in which bouldery, silty sand made up a large part of the fill. This material was placed on a 12" layer of bouldery bottom course to determine if proper drainage would render this more economical material suitable for construction on ice. These two sections are between stations 58-59+00 and 60-63+00. (Plate 2)



CAMP TUTO AREA 1955

SCALE: 1"=800'

C 5938 PLATE # 1 C 5938



PROFILE
RAMP ROAD
TUTO, GREENLAND 1955

PLATE # 2

(f) Crushed rock was used as a test fill in several sections: Station 33-34+00 contains about 18 to 20 inches of crushed rock on ice, Station 59-60+00 contains 18" of crushed rock placed on a 12" bouldery bottom course, and Station 66-67+00 contains a 12" section of crushed rock placed on the ice. In addition crushed rock was spread at various places as topping (Plate 2). Material used was unscreened and the largest size is 2 inches. Pads of crushed rock 3 and 6 inches thick were placed as berms near station 60 to further determine the minimum thickness of this material suitable for a roadway on ice.

(g) Tentative conclusion on test fills: The ideal fill would be two feet of clean bouldery material with a six inch maximum topping of crushed rock. Fill thickness is partly determined by snow depth and this is a factor on which we have little accurate information. Based on observations of next spring it may be possible to consider a somewhat modified, perhaps more economical, road cross section.

(h) As will be mentioned below, this roadway should be protected by berms, diversion wings, and made as dust free as possible.

(4) Unique Problems and Their Treatment

(a) Perching of Roadway: The ice surface of the lower ramp in the vicinity of TUTO melts down at the rate of several feet per season. This melting is nearly halted by the placing of a 2½ foot fill on the ice surface. Therefore, a road placed on the ice gradually becomes perched. That is, the elevation of the road surface gradually increases above that of the surrounding ice. A crown of unmelted ice is formed beneath the road. In the lower road this has become on considerable size. The top of an original five foot thick fill in testlane three is now about 12 feet above the surrounding ice; there has been melting of the unprotected ice of nearly seven feet since mid-July of last year. At station 30 an ice crown of nearly five feet was discovered this July when the old roadway was removed. Already the transverse road finished 22 July 1955 is perched on a 30 inch ice crown.

1. The problems inherent in this perching are, (1) an over-steepening of the road shoulder slopes with subsequent slumping and erosion, (2) development of a dangerously steep shoulder, and (3) perching of drainage features such as culverts and inverted drains. If uncontrolled, this perching would limit the usefullness of the road to a very few years in the lower portion of the ramp.

2. The construction of berms along both road shoulders greatly limits the damaging effect of perching. Test berm sections were constructed at various points along the roadway and consisted of 12 inch pads of silty sand 25 feet wide. Their effect is to widen the ice crown formed and maintain the road slopes as constructed. The width and minimum thickness of the berm might be further defined by tests next season. Probably these factors will vary on different parts

of the ramp as the amount of yearly ice ablation may vary considerably. The effect of berms is much less in the transverse road of course, for perching immediately diverts the streams away from the culverts and along the upper road shoulder. It is probably best to use open-bottomed drainage structures in which the streams will continue to cut through any ice crown formed beneath the roadway.

(b) Drainage in Transverse Road: Four types of drainage structures were constructed to convey melt stream flow through the transverse road. These were; (1) 36 inch standard ARMCO culvert, (2) oil drum culvert in which oil drums (55 gal.) were cut and welded, (3) inverted drain using clean bouldery material placed directly in the stream and (4) half ARMCO culvert placed on wooded sills. One culvert was placed directly in a channel cut in the ice stream bed, the other laid on hand placed rock bedding.

1. Very shortly after placing the transverse road fill, ice melting produced a crown under the road and flow was diverted away from the culverts and along the upper shoulder of the road. A very small amount of water continued to flow under the culverts. All culverts except the half-ARMCO ceased to function fully after one month. Nearly all the flow along the upper shoulder was transmitted by the half culvert which permitted the stream water to cut through the ice crown.

(c) Dust Problem: Small amounts of surface dust and dirt increase the melting of ice exposed to sunlight. This is very marked near the lower end of the ramp road. Prevailing wind carried dust to the ice south of the road; small streams have spread silt and sand over a distance of several hundred feet from the south road shoulder. As a result, lowering of the ice south of the road is considerably greater than north of the road. This increased melting of ice near the road shoulder tends to draw melt water streams over near the road edge and increase erosion.

c. Movement Survey

(1) The glacial ice forming the road subgrade was found to show seasonal movement in the survey made by Dr. Walter Schytt in 1954. This movement is not constant, but varies in different parts of the TUTO Ramp. Above the hummocky zone, at about station 31+00, movement over the summer may reach six feet laterally, toward the glacier edge; below the hummocky zone, less that a foot. Vertical movement is quite small.

(2) While it was not intended to assume the continuation of the detailed work of Dr Schytt, it was felt important to define the movement of those portions of the glacier traversed by the ramp road. Incidentally, it is hoped that the results of Dr Griffiths ice movement survey during the 1955 season will be available to supplement our study.

(3) Ten movement pins were placed in the road. These were at stations 10+00, 20+00, 28+00 31+50, 32+60, 36+49, 52+20 and 7+00 in the transverse road and at three points in Test Lane Three (Station 10+00 and 14+00). Three triangulation surveys were made on June 27, August 6 and August 19, 1955, using the base line and survey points established by Schytt in 1954. Elevation changes in the movement stakes were established by leveling from North point of the triangulation base line.

(4) Computations of the movement have not been completed during the field period. Sample results give however:

Period 27 June through 7 August

	x	y	z
Point 1	-0.33 ft	-0.71 ft	Not detected
2	-0.27 ft	-0.55 ft	" "
4	-0.27 ft	-1.60 ft	" "
20	-0.19 ft	-0.63 ft	" "

(5) Points 1+00, 2+00 and 20+00 are below the hummocky zone and point 4+00 is in that zone. The movement is predominantly toward the glacier edge and slightly southward. It is significant that differential movement exists as this should tend to shorten sections of the road or destroy their alignment. Such was not detected in the ramp road during this season.

(6) There is considerable evidence that the bench marks established by Dr Schytt, and used in this survey, are in no sense permanent. They are simply large boulders. If surveys of a detailed nature are to be carried out in coming seasons it is quite important to construct proper benches and establish a new triangulation net. Present best judgement gives the following method of obtaining relatively permanent survey points (following Mr Spencer Taylor): A rod should be drilled 12 to 15 feet into permafrost. In order to avoid heaving of this pipe in the active zone it is enclosed in a pipe several inches larger in diameter which may extend 3 or 4 feet below ground surface. The space between the pipes is filled with grease, and the outer pipe capped and protected.

d. Soils Testing

(1) The following schedule of soils tests were carried out;

(a) Thaw Penetration Test Pits: Density to 24 inches where possible, weekly measurement of water content.

(b) Surface Temperature Setups: Weekly water contents and periodic cone penetrometer measurement of compaction.

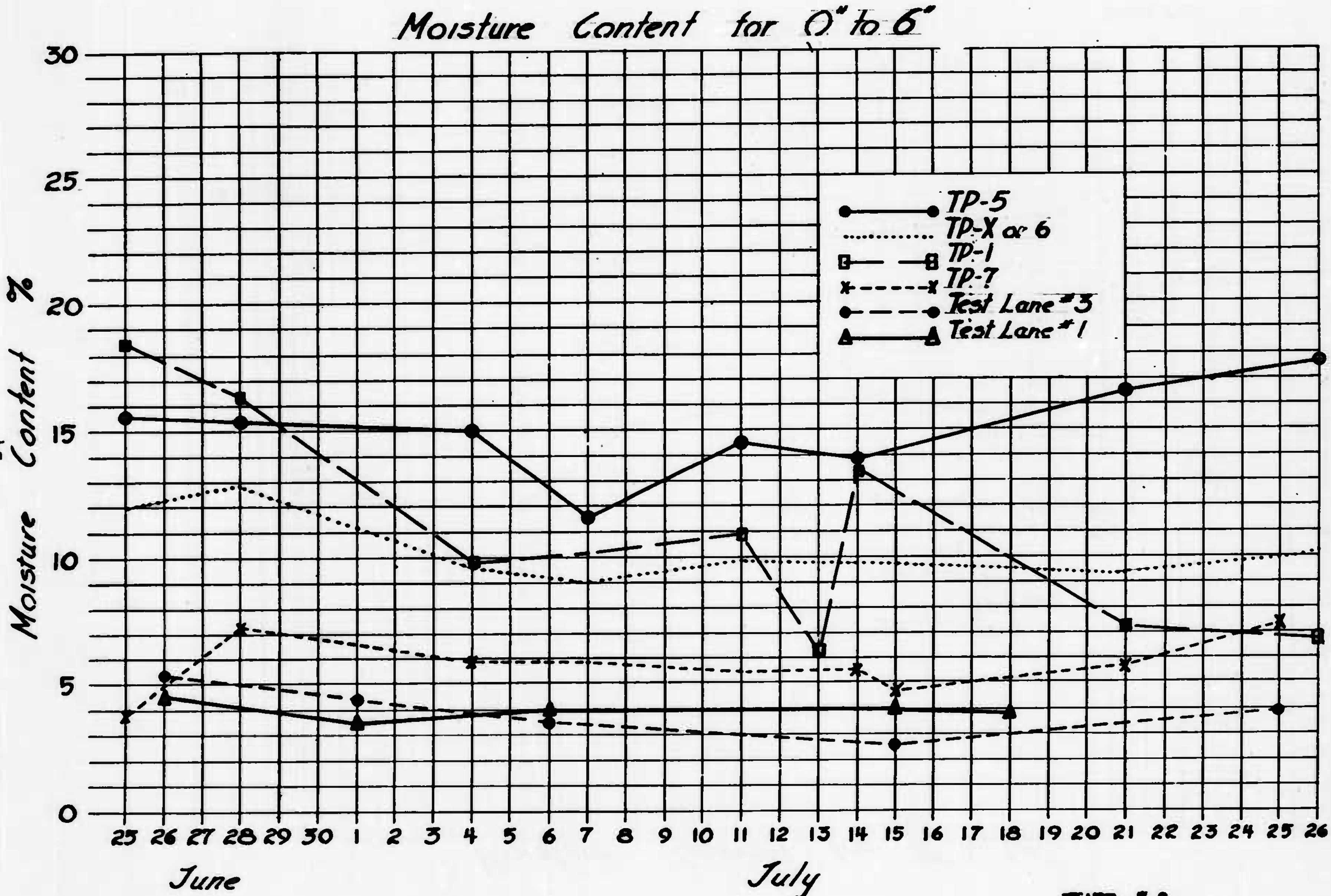

Moisture Content for 0" to 6"
30
25
20
15
10
5
0
Moisture Content %
TP-5
TP-X or 6
TP-1
TP-7
Test Lane #3
Test Lane #1
25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
June
July

PLATE # 3

Moisture Content for 12" to 18"

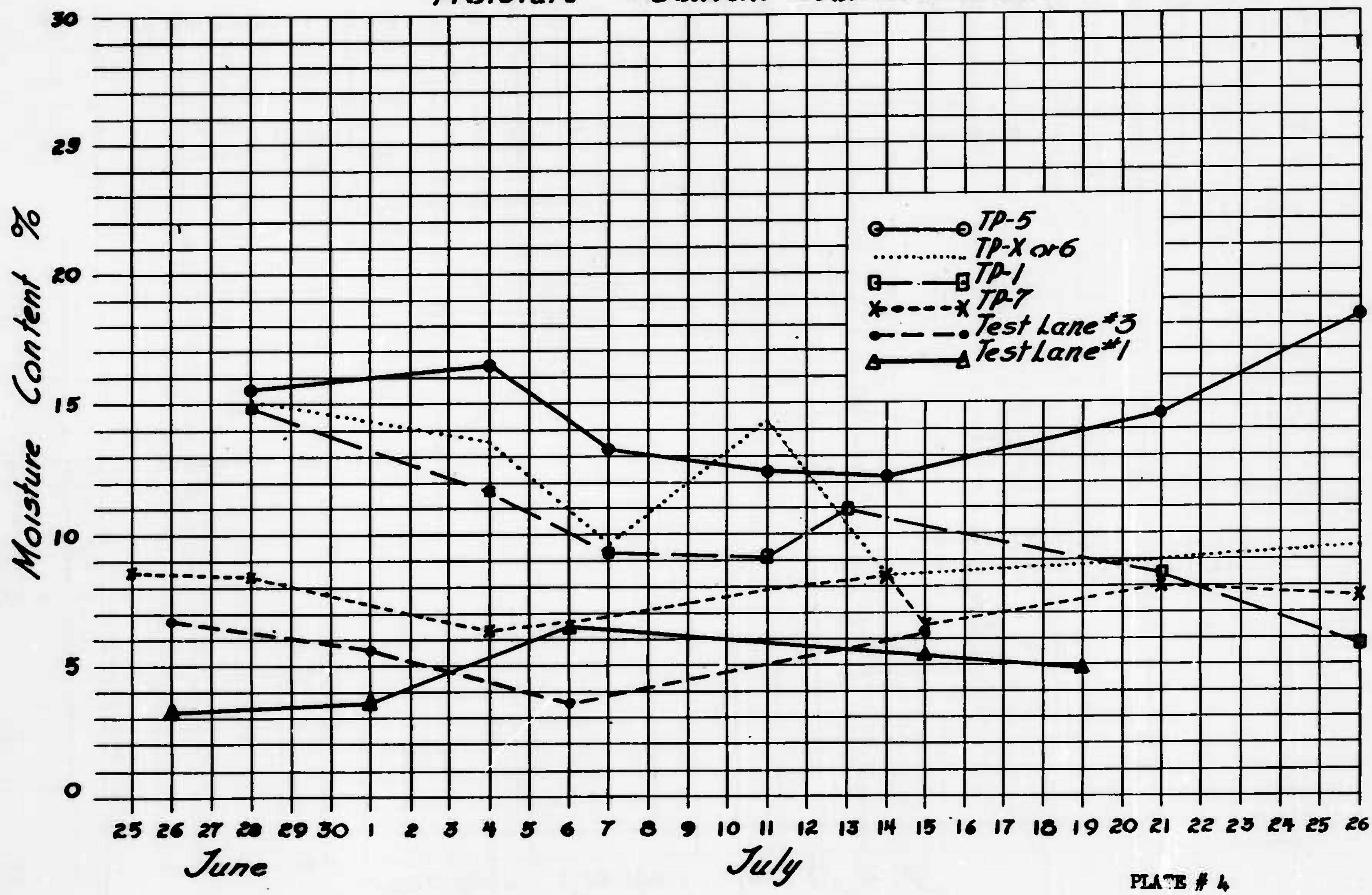


PLATE # 4

(c) CBR tests were run twice in all test lanes at several depths, and at several points in the newly constructed road.

(d) Points of failure in the old road were studied for density, CBR, and water content, to determine possible cause of failure.

(e) All borrow materials were studied for grain size distribution down to the no. 200 seive. Samples of all of these and other pertinent soils in the area have been collected for further laboratory analysis in Boston, Massachusetts. Photographic study was made along with the other tests.

(2) The bulk of the soils test made in Greenland have not as yet been analysed and many further tests will have to be carried out in the laboratory before conclusions may be drawn. Sample field results are given below:

(a) The finer material used in topping, and in the portion of the road which failed contained 10 to 20% of material of silt size and smaller, and but a few percent grains larger than 3 inches. Borrow used as base course this season contains 80 to 90% of grains larger than 2 inches.

(b) The unit dry weights of fill and undisturbed ground are both about 115 to 125 lbs/cu ft. CBR tests have a wide range, reflecting the bouldery nature of the soil. Values vary from 15 to 60% in the compacted roadway but may drop to less that 1% in areas of failure.

(c) Water content of the natural soils vary with time and depth. Plate 3 and 4 show typical variation in some of the thaw penetration test pits. It is noteworthy that variation is similar in any one pit to considerable depth. Note TP-1. The wide variation in water content with time for TP-1 and 5 reflects variation in the water table. These pits are located in relatively low areas from which material was borrowed during the 1954 season. The water table may change quite rapidly from week to week.

e. Thaw Penetration Studies

(1) Study of this penetration was carried out in seven areas, as shown on Plate 1. Depths of thaw penetration were determined by weekly and semi-weekly pits dug to frozen ground. In addition, in the three test lanes, 1, 3 and 4, (Plate 1) the height of the frost table could be determined indirectly by measurement of ground temperatures.

(2) Thaw penetration varies with the meteorological conditions and with time. Plate 5a and 5b shows typical variation of the frost table in thaw penetration areas 5 and 7. Fluctuation is similar

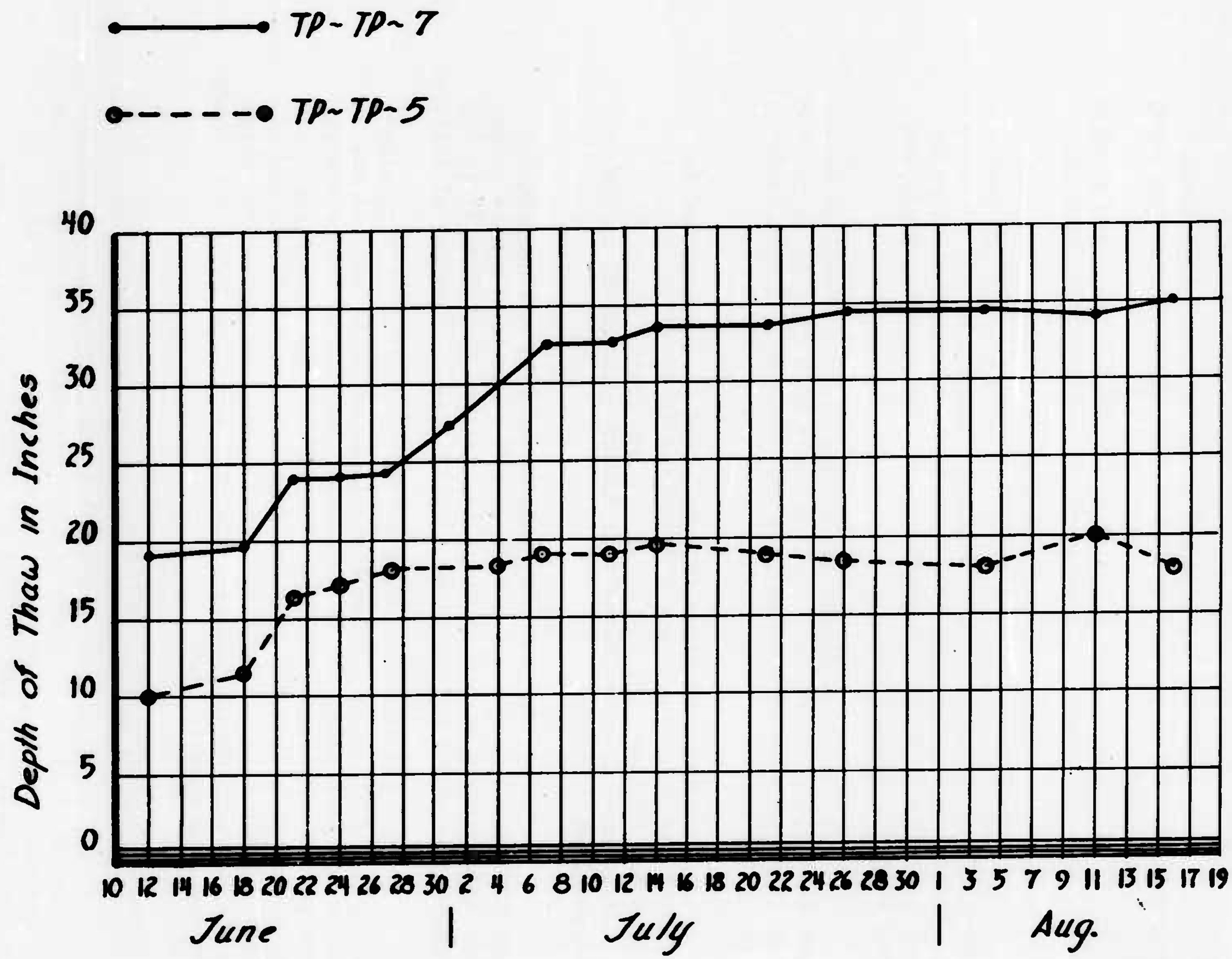
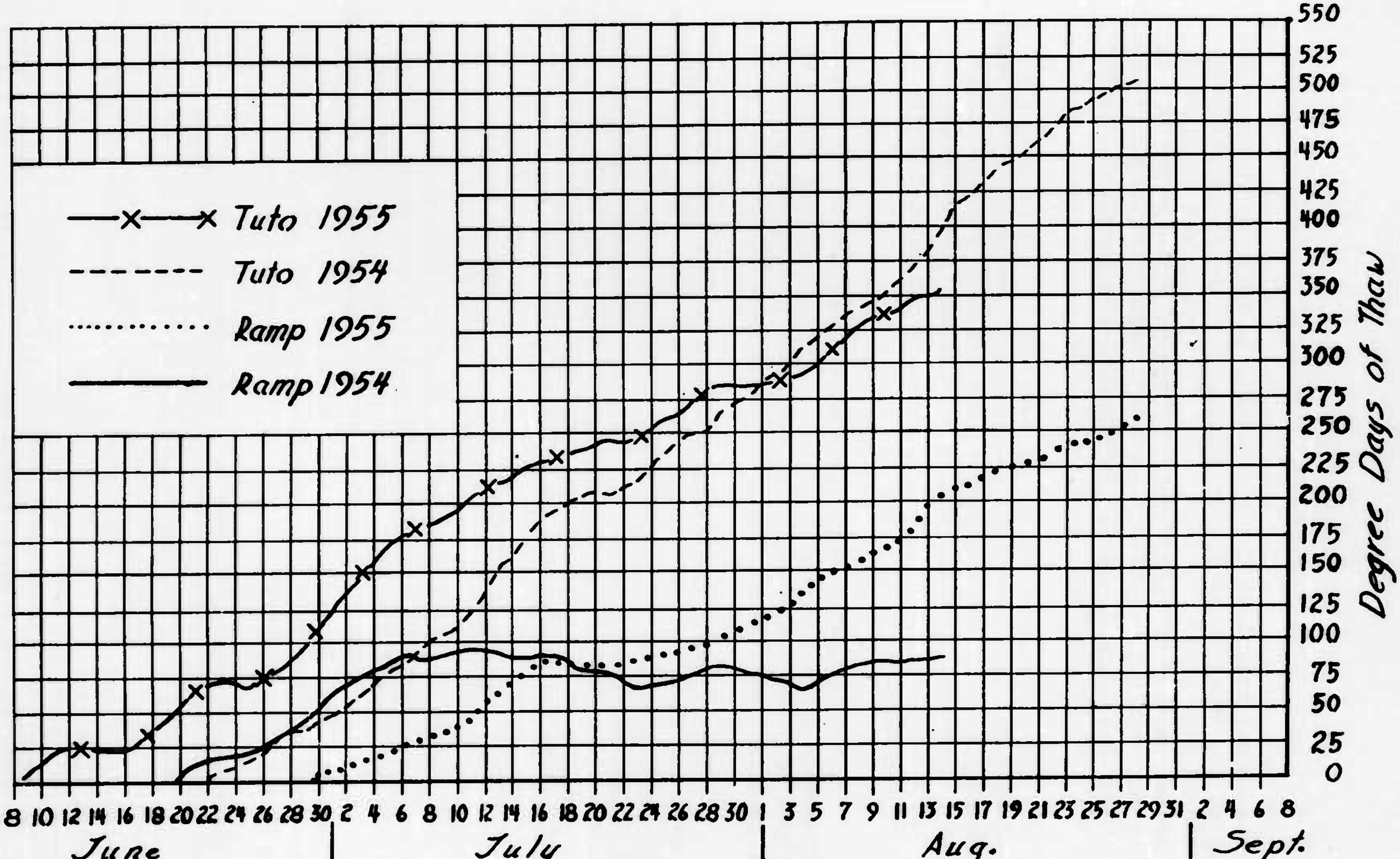


PLATE # 7a

Thaw Penetration Test Pits



Degree Days for 1954 & 1955

PLATE # 5b

although the actual height of the frost table is quite different. The rapid drop of the frost table can be correlated with the relatively warm weather of June and early July, when the thawing was accelerated. With the cooler weather of July, bottom curves of Plate 5a and 5b, the frost table has remained relatively constant. Since the tenth of August the frost table has begun to rise. Furthermore the ground is locally frozen at and near the surface since 20 August.

(3) The lower curves of Plate 5a and 5b compare the climates of this and last year TUTO and at about 1 mile up on the ramp. At TUTO, the degree days of thawing for this year far exceeded those of last year. However, by early August this situation was reversed. A similar trend appears for the ramp station, the reversal however, occurring by the first week of July.

(4) The early thaw was a major obstacle to our complete study of the thaw penetration this season. Plate 5a and 5b indicates that the thawing season was nearly two weeks advanced in early June. Project 1 personnel arrived at Camp TUTO on 12 June 1955.

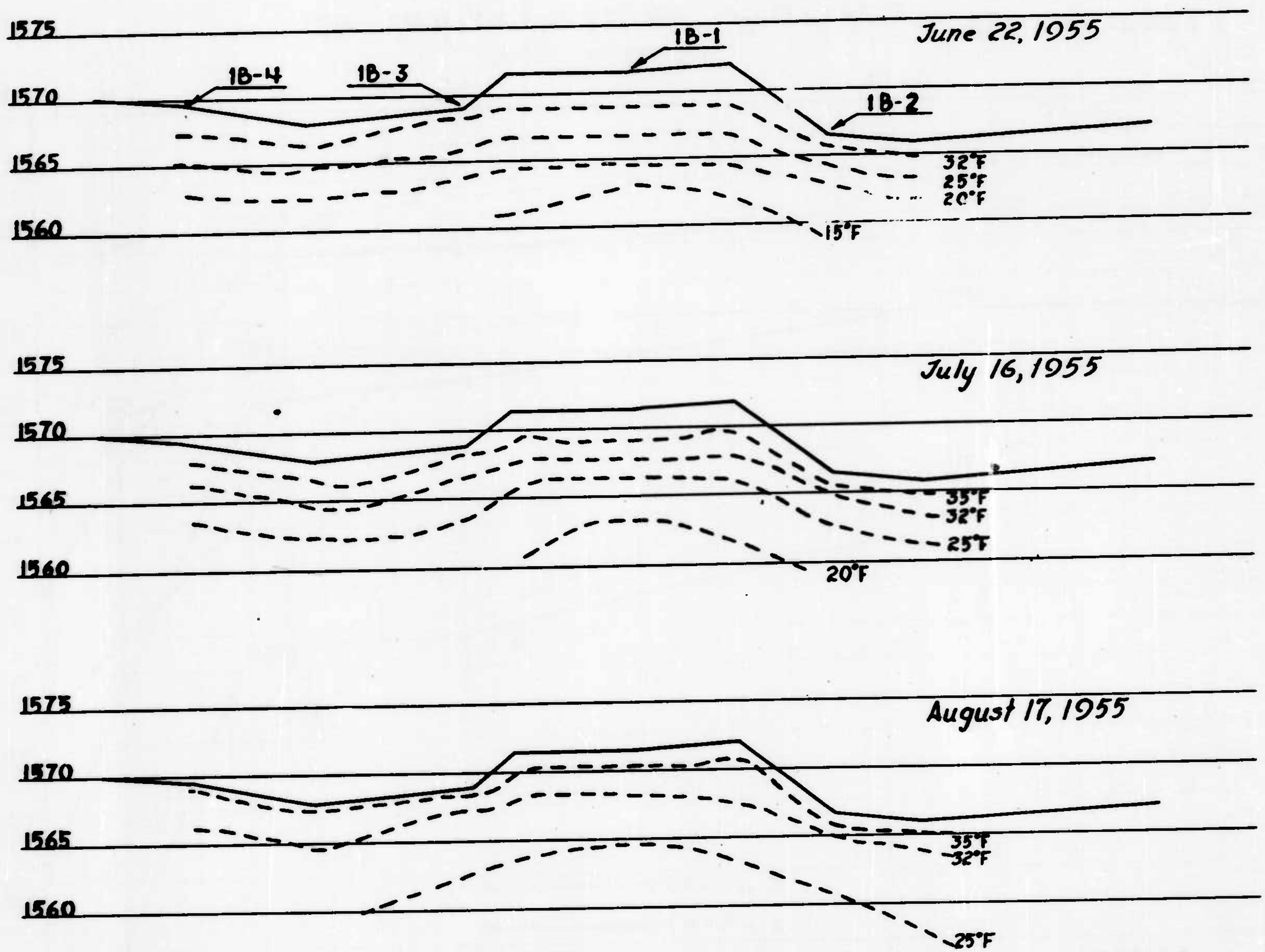
(5) Ground thermocouples placed in the test lanes permit more detailed study of the thawing in these areas. The temperatures under test lane 1, behind the maintenance area, are shown during June, July, and August in Plate 5a and 5b. This is a three foot fill and the frost table has dropped during this period from 2½ feet to 3½ feet. However, the presence of the roadway obviously tends to insulate the ground beneath and causes a ridge in the frost table (32 degree isotherm)

(6) Data was collected to bear on the evaluation of the surface transfer coefficient in this region. This included temperature gradient measurement in the ground and in the air column above, surface temperature measurement and wind velocity profile measurement. Sample data is shown on Plate 7 for test lanes 1 and 3, in which it is seen that temperature increases vary sharply at the ground surface decreasing upward with a gradient depending on wind velocity. All of this data will be analysed at the Arctic Construction and Frost Effects Laboratory in Boston this coming winter.

2. Obstacles Affecting Project 1 (1955 season)

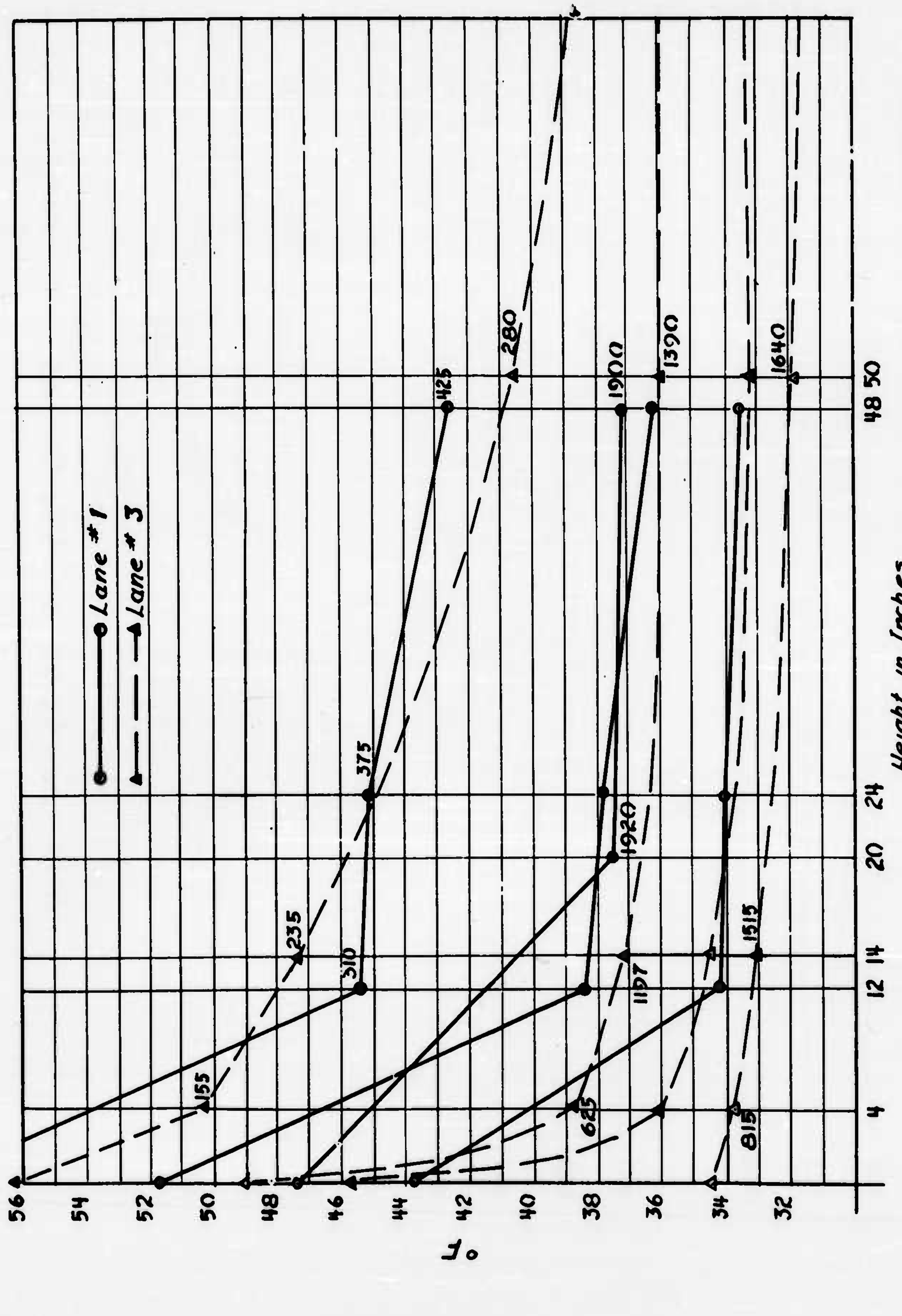
a. Personnel of Project 1 arrived in Greenland two to three weeks after the onset of thawing and were therefore unable to make a complete study of frost action this season. This was unforeseeable, as the situation this year was apparently unique.

b. Nearly a quarter of the road built this year was a replacement of road built in 1954, which failed this June. Failure was due to an unfortunate choice of material for fill.



Cross - Sections of Isotherms

PLATE # 6



Air Temperature Profiles

PLATE # 7

COST EVALUATION OF RAMP ROAD

Greenland 1955

1. EQUIPMENT	2. MONTH	3. TOTAL POSSIBLE HOURS	4. TOTAL ACTUAL HOURS	5. TOTAL DEADLINE HOURS	6. TOTAL INOPERATIVE HOURS	7. TOTAL COST OF EQUIP col(3)x hr rate	6. LOST TIME %	9. TOTAL MAINTENANCE HOURS	10. TOTAL DEADLINE MECHANICS HOURS	11. TOTAL OF COLUMNS 9 & 10	12. MAINTENANCE COST COL. 11x$1.42 ea.	13. TOTAL FUEL USED GALS.	14. TOTAL FUEL COST COL. 13x15¢/gal.	15. TOTAL MAN HOURS includes all const. pers.	16. TOTAL COST MAN HRS. col. 15x $1.42/hr (av)	17. TOTAL COLUMNS 12 & 16	18. GRAND TOTAL COSTS col. 7, 14, & 17
TRACTOR CRAWLER D-6 DED	JUNE	255	187	35	33	255x 3.90 $ 994.50	28.3%	102	35	137	$194.54	952-D	$142.80	900	$1278.00	$1472.54	$ 2809.84
	JULY	900	660	159	81	900x3.90 $3510.50	26.7%	258	159	417	$592.14	2604-D	$390.60	2776	$3941.92	$4534.06	$ 8434.66
	AUG	1134	769	98	267	1134 x 3.90 $4422.60	32.2%	357	98	455	$646.10	2654-D	$398.10	3829	$5437.18	$6083.28	$ 10903.98
		2289	1616	292	381		average 29.5%	717	292	1009	$1432.78	6210-D	$931.50	7505	$10657.10	$12089.88	$ 21948.48
TRUCK DUMP 9 1/2 CU YD DED	JUNE	255	168	23	64	255x5.80 $1479.00	34.1%	95	23	118	$167.56	810-D	$ 91.50			$167.56	$ 1738.06
	JULY	900	669	34	197	900x5.80 $5220.00	25.8%	228	34	262	$372.04	2250-D	$337.50			$372.04	$ 5929.54
	AUG	1449	888	97	464	1449x5.80 $8404.20	38.7%	385	97	482	$684.44	3736-D	$560.40			$684.44	$ 9849.04
		2604	1725	154	725		average 33.9%	708	154	862	$1224.04	6596-D	$989.40				$ 17316.64
3/4 YARD TRUCK MTD & 3/4 YARD CRAWLER SHOVEL	JUNE	65	64	11	10	85x8.00 $680.00	24.8%	32	11	43	$ 61.06	227-G	$ 34.05			$ 61.06	$ 775.11
	JULY	303	235	25	43	303x8.00 $2424.00	22.5%	92	25	117	$166.14	715-G	$107.25			$166.14	$ 2697.39
	AUG	394	259	40	95	394x8.00 $3152.00	34.4%	114	40	154	$216.68	900-G	$135.00			$218.68	$ 3505.68
		762	558	76	148		average 28.6%	238	76	314	$445.88	1842-G	$276.30				$ 6978.18
2 1/2 TON DUMP TRUCK	JUNE	47	47	0	0	$ 77.55	.0%	18	0	16	$ 25.56	98-G	$ 14.70			$ 25.56	$ 117.81
	JULY	200	133	40	27	200x1.65 $ 330.00	33.5%	70	40	110	$156.20	315-G	$ 47.25			$156.20	$ 533.45
	AUG	52	33	8	11	$ 85.80	36.5%	16	8	24	$ 34.08	126-G	$ 16.90			$ 34.08	$ 138.78
		299	213	48	38		average 28.6%	104	48	152	$215.84	539-G	$ 80.85				$ 790.04
TRACTOR, CRAWLER D-7		88	80	3	5	88x3.25 $ 286.00	9.0%	33	3	36	$ 51.12	218-D	$ 32.70			$ 51.12	$ 369.82
25 YD ROCK CRUSHER		65	60	16	7	85.500 $ 425.00	23.5%	22	16	40	$ 56.80	180-D	$ 27.40			$ 56.80	$ 509.20

Grand Total Cost $47,912.36

PLATE #8 C 5938

c. Fire, on 21 June 1955, destroyed the Project 1 Soils Laboratory and equipment, delaying soils testing by three to four weeks. Due to the kindness of Mr. Arthur, of SIPRE, some equipment was made available to Project 1 during this delay.

d. A small shovel and other heavy equipment shortages limited us from accomplishing the full plan of tests of 1955. Specifically it was not possible to carry the transverse road as far as the ice tunnel. There would have been valuable lessons to learn had this been possible, and certain assistance given to personnel working in the ice tunnel area.

3. Suggestions for Future Road Construction

a. The need for two survey parties is apparent. There is a great deal of time required in carrying out a thorough movement survey, laying grades, and running periodic location surveys and cross sections. A 3/4 ton truck should be made available as well as a theodolite, 2 levels, 1 transit, and supplementary equipment.

b. The most promising source of coarse borrow appears to be the southward extension of borrow area E and the area north of there near this year's rock crusher site. A few thousand yards of good coarse borrow are located just west of the Transportation Corps maintenance area. Material suitable for topping is abundant in the TUTO area.

Annex B

PRELIMINARY REPORT
Project 2 (Transfer Point)

PROJECT ENGINEER: 1/Lt Richard L. Makinen

1. Introduction: The 1st Engineer Arctic Task Force was assigned the responsibility of preparing plans and specifications and constructing a transfer point at the end of the ice cap road, which had been built by the 1st Engineer Arctic Task Force during the 1954 Research and Development season. The need for an earth-fill type transfer point in the ramp area became apparent in 1954 when serious difficulty was encountered while transferring cargo from wheeled vehicles to snow surface transport. It was decided that the area above the shear plane hummock zone would be most suitable for utilizing standard Engineer equipment in the operations of storage and transfer.

2. Description of Work

a. The work was accomplished during the period 15 - 25 July 1955. Located directly adjacent to station 45+00 of the ice cap road, its dimensions are; 75 feet long, 15 feet wide, and 4 feet high.

b. A gasoline powered ice-auger was used to excavate six inch circular holes to a depth of 5 or 6 feet. Rounded 4 x 6 inch timbers were placed in the holes and allowed to freeze in place. Pierced steel plank was covered with salvaged canvas and attached to the timbers to serve as a revetment. The enclosed area was filled with random borrow topped with 6 inches of fine gravel.

c. The original construction plan called for the building of a larger transfer point, using the same method of construction, at this point. Failure, however, of the ice cap road to support any traffic brought construction to a standstill. Rebuilding of the road was completed on 15 July, but revision of plans for this project calling for estension of the road to the vicinity of station 100+00 completely deferred any further effort on the transfer point.

d. At station 96+00 an 80 foot circular earth and rock fill pad was constructed to serve as a provisional transfer point.

Annex C

PRELIMINARY REPORT
Project 3 (Snow Compaction)

PROJECT ENGINEER: Paul A. Beigbeder

1. Introduction

a. This report covers the construction of a 200' X 10,000' compacted snow runway at Station "FIST CLENCH", Greenland during July and August 1955 and its use by aircraft during September.

b. Reasons for the operation were:

(1) To evaluate the performance of the equipment and procedures used.

(2) To determine the necessary manpower, materials and supplies required for similar operations.

(3) To determine the traffic capacity of the snow pavement in terms of aircraft wheel loads.

c. The construction of the runway was carried out by 2 Project officers and 41 enlisted men (10 assigned to camp details) of the 1st Engineer Arctic Task Force.

d. The equipment used to construct the runway included the following:

(1) 4 - Blaw-Knox Corrugated Steel Rollers, 5' diameter

(2) 2 - Blaw-Knox Snow Drags, 28' wide

(3) 4 - Pulvi-Mixers with Tri-D burners mounted on hood

(4) 2 - Steel skids 8' X 15', for 11.5-50 ton Bros Rubber Tired Rollers

(5) 2 - 11.5-50 ton Rubber Tired Bros Rollers

(6) 2 - Adams Ski Mounted Graders, towed type

(7) 3 - D7-Low Ground Pressure Tractors

(8) 1 - D8-Low Ground Pressure Tractor

(9) 2 - TD-14 Tractors

(10) 1 - D6 Tractor

2. Method - Runway processing method was as follows:

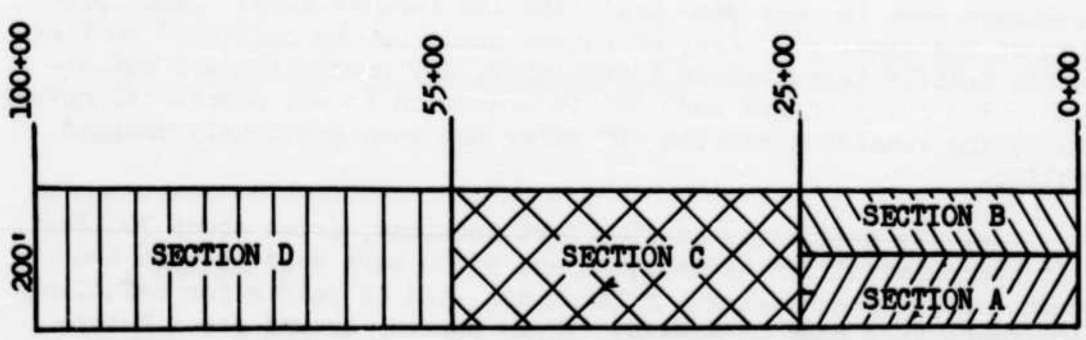
a. Using the Blaw-Knox drags, the entire area for the runway was dragged, leveling all drifts. Since the surface was initially relatively level there were no local areas, normally requiring an Adams Grader to cut and fill, in which the drags were ineffective.

b. Immediately after dragging, each section of the runway was compacted, using the corrugated steel rollers. One pass of the rollers was sufficient to obtain the desired compaction.

c. A 12-hour hardening period was allowed after rolling to provide a better operating surface for the tractors. The runway was then processed with Pulvi-Mixers, using 3 machines in tandem. Previous snow compaction experience indicated that three passes of a Pulvi-Mixer produce (without heat) the maximum density obtainable with this machine. The passes must follow each other in as rapid succession as possible. The latter requirement is most essential when heat is being applied to snow. In this operation the runway was given 1 coverage (3 machines) without heat (dry processing) and 1 or 2 coverages with heat (wet processing). These operations are more fully described following sketch under "d" below.

d. Immediately following the last Pulvi-Mixer coverage (wet process) the steel skid carrying the Bros Roller (gross wt 29,000 lbs) was towed over the processed surface to compact the moistened snow. In some instances where the surface left by the last Pulvi-Mixer was not level the grader was used to lower the high spots before using the skid.

e. The runway was processed in the alphabetical order of sections as shown:



3. Processing

a. Section "A" was being processed when Project Engineer arrived at the site on 12 July, by one Pulvi-Mixer with its hood and burners removed and the rotor working to a depth of 3 feet. This unit was followed by 2 Pulvi-Mixers with their rotors operating to a depth of 27 inches. All rotors were operating in reverse, i.e., undercutting and throwing the snow forward. Differentials had been burned out of 2 Pulvi-Mixers and 1 of the units was still deadlined. The processed surface was a series of frozen waves some two feet deep. The grader was put to work leveling this section while the Pulvi-Mixer rotors were removed, then reinstalled to give proper direction of rotation.

b. Section "B" was processed dry (1 coverage) followed by a single heat coverage. Surface appearance indicated that processing had not been uniform. To determine the location of any soft or weak areas and the extent of the non-uniformity, a Bros roller, imposing a 6200 lb wheel load, was towed over both Sections "A" and "B". The isolated areas which failed in each section were graded and both sections were given another heat coverage with the rotors cutting to a depth of 14 inches.

c. Section "C" was given 1 coverage of the dry processing and 1 coverage with heat (wet processing). During the processing of this section considerable difficulty was experienced in keeping 3 Pulvi-Mixers in operation. The magnetos, used to provide the spark for the burner, began to have shaft failures with some regularity as did the fuel pumps for the burners. All spare magnetos and fuel pumps had been put to use and suffered damage before the first coverage with heat was completed. In order to keep the job going, part of section "C" was processed with a single machine. The resulting poorly processed surface showed so little evidence of heat effects that instructions were given to reprocess the section only when 3 Pulvi-Mixers were available in operating condition and that no deviation from these instructions would be permissable.

d. The first 5000 feet of runway had taken approximately 30 days to complete, the stock of spare parts had been depleted, and the Pulvi-Mixers were in very poor condition for further work. Since processing of the final 5000 feet of runway could not be completed on time to permit traffic tests before 1 September, dry processing was not attempted. The Pulvi-Mixers were put in operation to wet process (1 coverage only) the remaining section "D" which had been previously dragged and rolled.

e. By processing in 2500 foot sections, areas about 300 feet long at approximately Stations 25+00 and 55+00 were used to turn the equipment around when making a return pass, and as points for refueling the equipment at 2 hour intervals. These turning around areas became considerably rutted by the processing equipment and saturated by spilled fuel. Observation showed that in addition to the snow particles becoming coated with fuel oil, excessive traffic gradually rounded them, the combination producing conditions not conducive to creation of a strong snow mass. Rather than delay traffic tests on the runway after section "D" was completed, the turning areas were given a coverage with heat (wet processing) by the 3 Pulvi-Mixers across the width of the runway.

f. On 15 August, approximately 1½ months after starting construction, the runway was considered completed, and testing of the surface began. The Bros Rubber Tired Roller was used as a test cart making 1 coverage of the entire strip with wheel loads of 7,250 lbs (gross wt 29,000 lbs). Parts of the turning areas and about 10% of section "D" failed. The roller was then consecutively loaded to produce wheel loads of 9,250 lbs (gross wt 37,000 lbs), 11,000 lbs (gross wt 44,000 lbs), and 13,000 lbs (gross wt 52,000 lbs). One coverage with each wheel loading was made. No increase in the area of failure developed. Between the tests made with the 7,250 and 9,250 lb wheel loads the tire pressure was increased from 70 psi to 100 psi. Wheel loads over 13,000 lbs were not attempted because no facilities existed for loading sand ballast (in 55 gallon oil drums).

g. Immediately after completion of traffic tests with the Bros roller, the turning areas at 25+00 and 55+00 were regraded and reprocessed with heat. The Pulvi-Mixers were towed as slowly as possible in an attempt to burn enough fuel out of the spoiled snow so that a stronger surface than produced by the first coverage might result. Reprocessing of the turning areas was completed about 24 August. On 26 August the first aircraft, a C-47, landed and taxied the entire length of the runway. Failures occurred at Stations 25+00 and 55+00. The failure at Station 25+00 was partly through a layer of new, unprocessed snow 2 to 4 inches thick. The failure at Station 55+00 was about 10 inches in depth in the processed layer. Snow in the turning area at Station 55+00 was removed to a depth of 2 feet and replaced with new snow from an area adjacent to the runway. Rebuilding of the latter area was completed on 1 September. The failure at Station 25+00 was not sufficiently serious to rework.

4. Testing

a. In the following week about 12 landings and takeoffs were made by loaded C-47s with no noticeable failure of the runway surface. During this period approximately 8 to 12 inches of snow which had either fallen or drifted on the runway, required daily dragging and rolling with the Blaw-Knox equipment. On 10 September a C-54, lightly loaded, made three landings and takeoffs. Takeoffs were made in 4,500 feet. Some failure of the processed surface occurred at Station 25+00. No failures occurred at the turn-around areas used by the aircraft except in the overlying unprocessed new snow. After the undersigned left "FIST CLENCH", 12 landings and takeoffs were made by a C-124 on 25, 26, 27, and 28 September. The landings on 27 and 28 September were made with a 40,000 lb pay load (gross wt 168,000 lbs). Temperatures during these landings are not known. During the C-54 landings, the air temperature was minus 10°f. Temperatures during construction of the first 5,000 feet of runway varied between +24°f and 0°f.

b. A scanning of measurements made with runway samples shows that generally there existed a processed layer 12 inches thick varying in density from 0.55 to 0.58 grams/cc. Section "A" showed evidence of processing to a depth of 30 inches whereas Sections "B" and "C" showed the unprocessed surface to be about 15 inches below the finished surface. On Section "D" the unprocessed depth was about 12 inches below the finished surface. No measurements for free moisture of the processed snow as it was discharged from the Pulvi-Mixers were taken. A comparison of the core samples along any one cross section showed a definite lack of uniformity in the processed depth as well as in the maximum and minimum densities obtained. This variance is attributed for the most part to the method of suspending the rotors and hood to the method used to regulate their operating depths or positions on the Pulvi-Mixers. The method of supporting the machine on skis and the transfer of any vertical movement of the towing tractor to the Pulvi-Mixer aggravated the deficiencies designed in the rotor regulatory mechanism. The skis have a poor bow angle and have a tendency to plow the processed area and to shove ahead the wetted snow discharged from the preceeding Mixer until the mass is of such size that the line of least resistance for the skis, is to slide over the mass. In doing so the rotor is drawn out of the snow at a faster rate than it can be lowered.

c. Another reason for the non-uniformity of the samples were the spasmodic performance of the Tri-D burner. It is doubtful whether all eight burners on each of the Pulvi-Mixers were operating together at any one time. Also, the heat transferred to the snow was dependent upon wind velocity which varied from day to day as well as within a day. The front of the Pulvi-Mixer hood is necessarily open to the atmosphere and the quantity of Air passing in front of the rotor determines the amount of heat available to melt the snow being handled.

d. Maintenance of the Pulvi-Mixers was limited to repairing and rebuilding the burner magnetos and fuel pumps. The damage to the two differentials before 12 July is laid to inexperience on the part of the Task Force personnel, who had never seen a Pulvi-Mixer operate in snow. There was considerable damage to the rubber air ducts feeding air to the burners. These ducts pass over the front of the hood and are subject to overheating and carbonizing from the hot gasses escaping from the hood. Of the seven tractors provided for this operation only one was operable on 1 September when the runway was completed.

5. Labor and Materials Expended

Approximately 10,000 man hours were required to build the runway. Some 18,000 gallons of diesel fuel and 1,700 gallons of gasoline were consumed by the engines and burners of the Pulvi-Mixers. The towing tractors used an additional 7,000 gallons of diesel fuel.

6. Experimental T-4 Snow Packer

a. Original plans called for processing the first 5,000 feet of runway with the Pulvi-Mixers and the last 5,000 feet with the Experimental Model T-4 Snow Packer. However, on 19 July, while making a dry run with the packer, the transmission driving the rear discharge rotor failed. Attempts made to process with only the processing rotor operating resulted in a surface too uneven to be acceptable. It was then decided to process the entire runway with the Pulvi-Mixers as delivery date of a new transmission was rather uncertain. The new transmission arrived and was installed by 13 August. Processing of about 6,000 linear feet was carried out without using the T-4 burners (dry process). The rotor was set to process to a depth of 30 inches. After four hours of continuous operation the T-4 was shut down and when started again, two hours later, the new transmission failed beyond repair. Failure was diagnosed as being due to faulty installation and freezing of the finely pulverized snow which had lodged between the two rotors, during the two hour halt.

b. Sampling of the area processed (dry) with the T-4 showed that the 30 inches processed was reduced to a 20 inch layer of fine uniformly pulverized snow, varying in density from 0.52 at the bottom to 0.58 at the surface with some readings of 0.62. Compared to the product produced by the Pulvi-Mixer the samples showed a marked overall uniformity of density, particle size and hardness.

c. Mr James Bender of SIPRE, in the course of his studies into the compressive strength of snow, sampled both the runway and the area processed with the T-4. A scanning of his measurements showed that the runway produced compressive strengths varying between 75 and 220 psi, whereas the T-4 area produced strengths of 110 psi in 11 samples measured.

7. Conclusions

a. The Pulvi-Mixer can be considered only as a shallow processing machine.

b. It cannot be stated whether or not the landings made in September could have been duplicated in July and August until traffic tests are conducted on surfaces similar to those produced by the Pulvi-Mixer and burners, at temperatures above 0°f.

c. Both Pulvi-Mixers and T-4 Snow Packers must be modified to correct their deficiencies and at the same time be redesigned to simplify their operation for use by inexperienced troops.

d. The curriculum of the Engineer School should be augmented to provide instructions in the use of the Mixer, Rotary Tiller, Soil Stabilization, Self Powered, Trailer Mounted, s o that troops can be made available for snow compaction who are familiar with the machine's principles of operation.

e. Imagination and foresight in the selection of spare parts in order to provide a sufficiency and still keep the number at a minimum is necessary. One part of the problem could be solved by allowing more lead time to requisition the needed parts.

f. The ability of testing aircraft to take off inside of 5,000 feet has raised some question concerning the need for 10,000 foot landing strips at elevation 7,000 on the Greenland Ice Cap.

PRELIMINARY REPORT
Project 3 (Testing of Processed Air Strip at FIST CLENCH)

PROJECT ENGINEER: James A. Bender

1. Introduction:

The testing of the compacted snow air strip at FIST CLENCH (Site Two) was the initiation of a long range program to determine the necessary requirements of a snow runway to support different types of aircraft. The testing procedures may be divided into three parts: (a) the taking of undisturbed samples and laboratory testing; (b) simple in place testing; and (c) large scale testing;. Procedures (a) and (b) require only two men and simple testing equipment. It is to be hoped that the first two procedures will give sufficient information to forecast the results of the large scale tests.

2. Laboratory Testing:

a. Undisturbed samples for testing were obtained from the the strip by the use of the SIPRE modified three inch auger. With this auger, vertical cores up to thirty-four inches long were obtained. Samples were taken on a profile normal to the strip at distances of 500, 1200, 2000, 3000, 4000, 5000, 6000, 7000, 8200, and 9500 feet from the west end of the strip. In addition, samples were taken from the first turnaround area (approximately 2500 ft). On the first three profiles, samples were taken at 20 foot intervals: on the remainder, at 10 foot intervals. Each core sample was visually inspected, the depth and structure of the processed layers noted. The core sample was then cut into section in order to obtain the density of the snow with depth. Whenever possible, the ultimate compressive strength and stress-strain relationships were obtained with the rate of loading and temperature noted.

b. In addition to the above, four pits for taking horizontal core samples for shear measurements were made. Two pits were dug at the 1200 foot mark: one on each side of the strip. Also, pits were dug in the first turnaround area and in the middle of the strip at the 8200 foot mark. The depth, structure, density and ultimate shear strength of each specimen was obtained, with again the rate of loading and temperature noted.

3. In-Place Strip Testing:

Rammsonde readings, whenever a core was taken, were made at noted time intervals. A number of pits were dug so that the temperature profile with depth could be taken.

4. Larte Scale Testing:

a. A four wheeled rubber tired Bros roller was pulled over the entire strip. First empty, and then with incresing load up to 13,000 pounds per wheel with a tire pressure of about 100 psi. The area where break throughs occured were noted and studied. Attempts were also made, using a rod and transit to note whether or not there was any defection of the strip (due to plate action) when the tractor and roller passed by.

b. The final testing was the successful landings and take-offs of both C-47 and C-54 aircraft.

5. Tentative Conclusions:

a. A very large amount of data was obtained including over 300 cores. 1,000 densities, and 400 ultimate strengths as well as stress-strain relations for the latter. The tedious, complete analysis must await the comfort and convenience of the home laboratory. However, the following generalized information may be noted:

(1) the depth of the processed layer varied from 0 to 26 inches with an average ob about 10 inches.

(2) the density of the processed layer varied from 0.50 to 0.65 with an average of about 0.56.

(3) the ultimate unconfined compressive strengths varied from a few psi to over 180 psi.

(4) the density of the compacted snow layer below the processed layer varied from 0.30 to 0.55.

(5) the density of the virgin snow layer below the compacted layer varied from 0.22 to 0.35.

(6) the information obtained from the laboratory and in-place testing is in good agreement with that obtained from tests of the wheeled roller and the aircraft.

(7) density figures may be necessary but definitely are not sufficient for predicting strip performance.

(8) although the processed layer is of primary inportance, if a strip is to support heavy aircraft, the depth of the processed layer and the characteristics of the snow underlying it become of importance.

(9) the strip as initially completed and with the warm temperatures of July, probably would not have supported wheeled aircraft in all places.

(10) it is believed that the air strip as it is now and with the present temperatures would support heavier aircraft than the C-47 and C-54, if it had about the same psi tire values.

Annex D

PRELIMINARY REPORT

Project 5 Part I (Basic Crevasse Studies in Blue Ice Valley)

PROJECT ENGINEER: Mark F. Meier

1. Introduction

a. Crevasses are tensile fractures, and the origin of the tensile stress is usually not hard to find. The stress can be calculated for an ice mass of simple shape, and at least the direction of principle tension can be determined for complex shapes. However, theories of fractures can not predict the size, shape, and spacing of the resulting crevasses, even if the stress field is completely known. Furthermore, the shape, size, and trafficability of a crevasse is determined not only by mechanical deformation, but also by the melting and deposition of ice and snow. Therefore the problem is complex and in order to thoroughly understand it one should know not only the stress and deformation, but also the accumulation and wastage of snow, the meteorological conditions, their effects, and the heat flow both in air and snow.

b. Considering the long-term aspect, this project is pointed t oward the following goals:

(1) To know in detail the geometry of a particular crevasse field and the essential differences between crevassed and uncrevassed areas.

(2) To be able, with a minimum of assumption, to compute stresses in the ice, and the combination of shear and normal stresses which are necessary to initiate a crevasse.

(3) To know the strain-history of a crevasse, how it forms, how it widens at the top, the bottom and the ends, how it closes, and the irregularity or jerkiness of its strains.

(4) To know the strains which occur with crevasse formation, and the readjustment of strains around a forming crevasse.

(5) To know the accumulation-ablation history of a crevasse shape.

(6) To know the cause, history of formation, and mode of deterioration of snow bridges; their structure; and the relation of factors of snow bridge formation and deterioration to meteorological conditions.

c. Field work in the summer of 1955, was a first attempt to attack the problem from as many aspects as possible, and to solve some of the severe instrumentation difficulties. The field party included:

Mr. James E. Conel, Precise Surveying

Dr. Jean A. Hoerni, Stratigraphy and petrofabrics

Mr. Mark F. Meier, Mapping, stress Analysis, and Project Engineer

Mr. William G. Melbourne, Micro-strains

Dr. Cornelius J. Pings, Jr., Thermal Measurements

Pfc Richard J. Van Atta, Radio Operator

Mr. Paul T. Walker, Meteorology

d. The project was sponsored by the Snow Ice and Permafrost Research Establishment, of the Corps of Engineers, under a contract with Occidental College, Los Angeles, California. Support in the field was given by the 1st Engineer Arctic Task Force, Corps of Engineers.

e. Field work was carried on from June 26, through August 23, 1955, in an area of relatively simple east-west trending crevasses about one mile north of mile post 13 of the TUTO-MORRIS STATION trail. This location (Blue Ice Valley) is in the feeding ground of a northward flowing major tributary of the Moltke Glacier. Four specific crevasses were singled out for detailed study; these included:

(1) A very young crevasse less than 0.1 M. wide in an area of crevasse-initiation.

(2) The next consecutive crevasse down-glacier, which is about 1 M. wide and is completely bridged.

(3) The third consecutive crevasse, which is 2M. wide and partially bridged.

(4) A large (3 M.) crevasse much farther down-glacier, not directly related to the first three.

f. Most of the quantitative crevasse work was confined to a vertical profile directed perpendicularly through the first three crevasses, with special concentration around the third crevasse. Most of the data obtained has not yet been analyzed, so the few conclusions presented here must be regarded as extremely tentative and subject to later confirmation or modification. This is a summary field report and does not constitute publication.

2. Surface Mapping

a. Accurate knowledge of surface topography is essential to stress and flow calculation and regimen studies. In addition, the number, shape, size, orientation, and spacing of all crevasses must be exactly known for a study such as this. Therefore an accurate plane table mapping program was instituted. Three completed maps include:

(1) A map of the complete study area and environs from about mile 12½ on the MORRIS trail north to about 300 M. north of the "Camp Crevasse" of the 1954 BLUE ICE party, an area of 18 sq km. This is to a scale of 1:10,000, with a contour interval of 5 M., and shows all known crevasses in this area except along the north edge where crevasse details will be filled in later by means of air photographs.

(2) A map of the main work area, 0.8 sq km, to a scale of 1 inch equals 50M., contour interval 1 M., showing all known crevasses and important instrument locations in the included area.

(3) A planimetric map of the area of detailed instrumentation (0.02 sq km) to a scale of 1 inch equals 10 M., with all instrument locations in the area located. This was especially constructed for the benefit of next year's party.

3. Subsurface Mapping

Detailed knowledge of bedrock configuration is essential to an understanding of the flow of a glacier, the resulting surface topography, and the crevasse pattern. The Blue Ice area was surveyed gravimetrically in 1954, but this work was uncontrolled and not of sufficient detail. In August, of 1955, a seismic party consisting of 2nd Lt Paul W. Poneroy, Mr. Charles R. Bentley, and Pvt Henry J. Dorman, did refraction and reflection studies in the area of detailed instrumentation providing some 91 determinations of ice thickness along two east-west and one north-south profile. Additional seismic checks of the gravity data were made at nearby locations. The seismic profiles indicate an irregular bedrock with down-glacier slopes of up to 30° and up-glacier (backward) slopes of up to about 15°. The overlying ice ranges in thickness from 850 ft to slightly over 1300 ft and has a very gently sloping surface. A noticable steepening of slope at the surface below crevasse number 3 corresponds to a steep up-glacier bedrock slope, as is suggested by theory.

4. Crevasse and Snow Bridge Mapping

This essential data was difficult to obtain because of the extreme irregularity of crevasse walls and snow bridges, and the difficulty of working within crevasses. Two vertical cross-sections were made of crevasse number 3 showing undisturbed firn with its ice bands, secondary deposits, and instrument locations. The snow bridge over this crevasse was surveyed along nine traverses spaced at 15 M. intervals. Some crevasse profiles, snow bridge traverses, and subjective observations show a striking volume of the original tectonic opening now occupied by secondary snow and ice deposits. The irregularity of crevasse sides and snow bridge undersides was striking; snow bridges were found that ranged in thickness from 2 inches to 10 feet within a distance of a foot or so. In general the tectonic volumes of the crevasses were in the shape of a simple planar wedge, but fractures often branched off through the snow bridge at a less steep angle. These fractures may be due to fracturing of the bridge by tectonic movement accompanied by slumping.

5. Precise Triangulation of Gross Surface Strains

a. In order to accurately know the stress-strain situation existing on the surface of a glacier it is necessary to know the velocity field (amount and direction of motion) existing there. From this one may also learn the rotations and translations and distortions of the blocks between individual crevasses; and the relationship between the velocity vector in space and the accumulation and/or ablation at that point.

b. Velocity measurements were carried out between 18 July and 14 August, 1955, using 36 - 8 foot by 1 1/8 inch wooden dowels set 7 feet vertically into the firn in an area around and between crevasses 1, 2, and 3. The dowels were arranged in six equally spaced parallel rows perpendicular to the crevasses in an area about 800 meters square. Dowels were placed equi-distant between crevasses to determine motion of the inter-crevasse blocks, and others near crevasse edges to detect any slumping toward the crevasses. A set of stakes were placed far to the east in a seemingly uncrevassed area to determine strains there.

c. Three 4 x 4 x 6 foot bench marks were set in an equilateral triangle located centrally in the velocity stake pattern. This bench mark system was taped and triangulated internally with each use. The bench marks formed the basis for a precise triangulation survey of the velocity stakes: horizontal and vertical angles accurate to a few seconds of arc were turned to nails in the top of each dowel, using Kern DKM-2 theodolites set on timbers driven into the firn and shielded from incident radiation. The bench mark system was it-self tied to two previously surveyed points of a nunatak seven miles to the south, and its approximate position will be tied to Griffiths' coordinate system along the MORRIS STATION trail.

d. Reduction of all these triangulation data requires laborious calculation not yet completed, and no conclusions can be given about gross strains or velocities at this time. However, appreciable angular distortions of the area were observed in the one month observation period.

e. There remained from the 1954 field season forty-three 2 x 4 x 10 fot timbers placed in a mile long line directed perpendicularly to the crevasse pattern; these were accurately taped and leveled in 1954. These stakes were resurveyed in 1955, to determine any east-west or vertical motion which might have occured, and were retaped to detect any north-south extension of the area. Preliminary results of the retaping show a prevalent extension amounting to about one-half of one per cent of the distance per year, at least in the southern part. This extension rate is consistent with that found from micro-strain measurements during the summer of 1955. Much of the extension apparently was taken up by the widening of crevasses, but appreciable stretching of uncrevassed blocks was also detected.

6. Micro-Strain Measurements

a. Essential to the Blue Ice program was a method for measuring tiny changes in the dimensions of crevasses. These measurements were carried out with a non-mechanical strain indicating system using a Baldwin SR-4 portable electronic strain indicator. This is a null-type instrument which detects change in electrical resistance of a wire strain gauge as the dimensions of the gauge are altered. The instrument is so calibrated that strains may be read directly; moreover, the precision is such that strains of the order of five millionths of an inch per inch of wire length were detectable and reproducible. The immediate advantages of such a system are obvious: The crevasses which were studied at Blue Ice Valley had rates of opening of the order of 1 mm per day - thus with the precision this system afforded we were able to obtain distinct, significant readings every hour or less. The strain and compensating wires were made of Advance alloy, and wire 0.004 inches in diameter was most generally used. The strain gauge wire was anchored securely to one wall of a crevasse, drawn taut and anchored to the other wall; construction of sufficiently rigid anchor points was probably the most difficult obstacle that had to be overcome. These gauges may be placed at any depth which is both accessible and sufficiently wide to allow a gauge-length within the tolerance range of the indicating instrument. This system, then, is a natural extension of surveying techniques in that it allows for the detection of dimension changes within crevasses and also reduced the time interval within which significant changes may be noted.

b. Several strain gauges were installed at various depths in one crevasse, and with the data obtained by this system we will later attempt to determine not only the rate of change of dimensions of the crevasse, but also the manner in which such changes are effected. As an example, here are three questions to which we hope to have a partial answer: 1. Is the opening rate independent of depth, or does the rate diminish with depth, and if so what is the functional relationship between rate, time, and depth as well as the other variables? 2. If the crevasse is locally spanned by a snow bridge, does the crevasse open underneath the bridge, or does it separate the bridge from the walls, or is it a combination of these depending upon the nature of the bridge? 3. Is the crevasse opening jerky or smooth, and do the openings correlate with meteorological conditions? Along with the interior gauges several others were placed on the surface across crevasses number 1, 2, and 2, and one was placed on the surface in the firn equidistant between crevasses. From the data derived from these, we hope to establish correlations between the three crevasses and the geometry of the area as well as obtaining some insight into the mechanism of flow of the glacier.

c. This system of measurement is rather novel in glaciological work, and several unexpected problems arose which had to be dealt with and solved before true progress could be made. One such obstacle was the problem of anchoring devices for the strain gauge wire; any slippage on the part of the anchors completely vitiates the measurements. Temperature changes required consideration. Shelters needed to be built for the strain wire to protect it from falling ice and water. Complete insulation was necessary to achieve reproducable readings. The installation of a strain gauge is a time consuming operation because work in a crevasse is tedious and dangerous; it generally requires the combined facilities of three men to obtain one man's work output, under more normal circumstances.

d. We found that the electronic strain gauge approach has very emphatic advantages over the mechanical space gauge both by its high degree if precision and also by the fact that once the wire gauge is installed, all readings can be made from the snow surface via lead wires. However, the mechanical space gauge serves as a check upon the electronic system insuring that the calibration is correct and that all components of the system are functioning properly. A check showed that space-gauge and strain gauge agreed within 8%, well within the accuracy of the space gauge.

e. Readings of the strain gauges were taken at least four times a day for several weeks. From August 14 through August 17, readings were taken every hour in conjunction with hourly thermocouple readings and meteorological observations in an attempt to establish short period correlation.

f. All reductions and interpretations of data will be included in the final SIPRE report. However, cursory inspection of the field data suggests that: (1) crevasse opening is jerky at the surface, but becomes more and more constant and uniform with increasing depth. (2) The crevasse opens in a wedge-like manner with the diminishing rate of opening with increasing depth affording a rough estimate of the total depth of the crevasse. These computed depths checked very well with depth information obtained seismologically.

7. Thermal Measurements

a. In addition to the temperature observations associated with the meteorological station, detailed thermal measurements were made upon a selected study crevasse. A total of sixty-one copper-constantan thermocouples were installed. Measurements were made with a precision portable null-type potentiometer calibrated to read directly in degrees centigrade. An equilibrium ice-water-air mixture was employed as a temperature standard. All observations were reproducible to within $\pm$ 0.2°c.

b. Nine thermocouples were installed in the crevasse air gap at depths from one meter to eighteen meters. In addition, a five unit horizontal traverse was employed in the air at a depth of five meters, and 5 meter penetrations at depths of 10 meters, 10.8 meters, and 14 meters. A total of 18 thermocouples were installed in these horizontal wells. Nine more were installed in two vertical wells drilled from the firn surface to depths of 4.7 meters and 6 meters. The crevasse snow bridge in the study area was instrumented at the top, mid-point, and bottom. Seven thermocouples were placed in the ambient air in order to afford correlations with the measurements of the meteorological station.

c. As the above instruments were installed during the summer, the associated temperatures were recorded at irregular intervals. During a 96 hour test extending from 14 August to 17 August, the temperatures at all 61 installations were recorded at one hour intervals. This test was a portion of an operation involving detailed strain gauge and meteorological observations in addition to the thermal measurements. A three hour test involving thermal observations only, was made on 21 August.

d. The thermal instrumentation and observations were adequate to define the isotherms in the region of the study crevasse. In addition, reduction and analysis of the field data may provide information on some or all of the following: (a) heat flux normal to the firn surface and crevasse walls; (b) the transient thermal shock in the spring and fall and its role in snow bridge collapse; (c) the freeze-thaw cycle of a snow bridge; and (d) the effective thermometric conductivity of undercooled ice.

8. Meteorology and Ablation Observations

a. A meteorological record was kept in Blue Ice Valley in an attempt to correlate this data with the other phases of the project and with the rate of ablation, as well as the record for its own sake.

b. A weather shelter was instrumented on 25 June. This contained a hygro-thermograph and maximum and minimum thermometers. A wind vane and anemometer (2 meters above snow surface), velometer, hand radiometer and barograph were also employed. The type of cloud cover and per cent of coverage were also noted. Three observations were made per day. Along with these weather observations, gross surface ablation was measured on five ablation stakes placed in approximately a fifty yard radius about camp. This procedure continued until 22 July, when the weather observations were cut down to two a day and ablation measurements much more seldom because of the decreased rate of ablation. This procedure was continued until 20 August.

c. On 28 June the height above the snow surface of the line of stakes left by last year's Blue Ice party was measured and the net accumulation for the winter determined. These stakes were again measured on 15 August so that the net accumulation or ablation for the summer could be computed. Velocity stakes set on 13 July and marked for ablstion at this time were measured on 21 August, providing additional data on accumulation and ablation.

d. From 14 July, to 19 July, 24 ablation stakes were placed at various levels in crevasse number three. Before these staked could be measured the crevasse was filled with snow by a storm on 22 July. On 2 August, 12 more stakes were set at a new location in the same crevasse. These stakes were remeasured on 19 August, and some ablation and accumulation data at various levels in the crevasse was obtained.

e. Density measurements were made throughout the summer. Periodic measurements were made near the surface of the snow to determine increase in water content. This information will be used in estimating the water-equivalent of surface lowering from the ablation stake measurements. Several density profiles were also made, both in pits dug along the walls of crevasses and the open snow and firn.

f. During the previously mentioned period of intensive taking of data from 14 August to 18 August, all meteorological instruments were read hourly. An attempt will be made to correlate the meteorology with the other data taken at this time.

9. Stratigraphy and Petrofabric Studies

a. Before some of the problems met in crevasse studies can be attacked or solved in a satisfactory way, further studies of firn undisturbed by crevasses are called for. Stratigraphic and petrofabric studies belong to this category of problems. Snow stratigraphy deals with the layered structure of a snow field and may yield data on the history of this field; necessary to this are profiles of density, hardness, wetness, temperature, and grain size. An important feature of the firn is the occurance of successive ice layers, which if properly interpreted, are of considerable help in determining the age of a particular firn sample and in correlating firn data from different locations, particular attention was given in the present work to the upper part of the firn corresponding to snow accumulation during the last two years. It was fortunate that a line of stakes planted by the crevasse study party of last year was available so that the net accumulation for the period extending from August 1954, to August, 1955, could be measured directly from the height of the stakes above the snow surface. It was perhaps unexpected to find that the net accumulation is very sensitive to even slight variations in the inclination of the surface slope. Near crevasse #3, for instance a net ablation of 0.10 meters during the period in question was recorded, whereas half-way between crevasses #3 and #4 a net accumulation reaching 1.70 meters was measured.

b. Pits were dug close to some of the stakes and a conspicious ice layer was found in each case at the depth indicated by the decrease of height of the stakes over the surface since August 1954. Almost 20 centimeters below this first ice layer, another strong layer corresponding presumably to the beginning of the summer 1954 was consistently observed. Pits were also dug at some locations where no stakes were available. These ice layer patterns were greatly facilitated by a comparison with results obtained close to the stakes.

c. A petrofabric study of a few ice layers (namely the detailed study of the ice texture in terms of the constituting single ice crystals) was carried out. The ice crystal structure has hexagonal symmetry and it is possible to determine the direction of the corresponding axis of symmetry (also known as optical axis) for a given crystal if it is mounted on a universal stage and examined between two crossed polaroids. The direction distribution of the optical axes of the various crystals forming a given ice mass is important in the study of the physical factors that may have previously affected this mass (stress, temperature gradient). In most cases, the distribution of optical axes has been found to be isotropic. However, the bottom of a few layers consisted of larger crystals, which showed a definite orientation of optical axes in a plane parallel to the snow surface.

d. The previous observations on stratigraphy and petrofabrics have been extended to the immediate vicinity of crevasse #4. Possible changes affecting the thickness and slope of ice layers when they meet the crevasse wall have been investigated. Petrofabric studies of the ice coating on the walls show that in general with a secondary weaker orientation in the vertical direction. This distribution is found irrespective of whether the sample of the coating is taken at the level of ice or snow layers in the adjacent firn. Finally a study of icicles has shown that they have a lamellar structure, the plane of the lamellae and their optical axes being normal to the vertical axis of the icicle. Further work on the theoretical interpretation of the previous results is in progress.

10. Major Problems

Crevasse exploration is laborious (nearly 80% of our available man-hours were spent digging, drilling, or belaying) and dangerous (especially from the possible fall of icicles and snow bridges). It is extremely important safety-wise and scientifically that crevasses be instrumented as early as possible in the summer, before the ablation season sets in and the snow bridges start to drip and sag. We were not able to do this for three main reasons - unfortunate pre-season delays in Camp TUTO, an abnormally early season and instrumentation difficulties. A party arriving in Blue Ice Valley before the start of the summer melt season in 1956 should be able, using our thermocouple and strain gauge installations, to note the important mechanical and thermodynamic effects of the warming up of the firn. Detailed recommendations for further studies and crevasse-working techniques will appear in the final report.

PRELIMINARY REPORT
Project 5 Part II (Basic Crevasse Studies)

PROJECT ENGINEER: Thomas M. Griffiths

1. Introduction

a. The primary function of Project 5 Part II has been to provide a reconnaissance picture of the gross geometry of crevasse patterns in the Thule area; this area being confined to the rough vicinity of the Camp TUTO-MORRIS STATION trail. This gross geometric pattern was intended to serve as an exploratory adjunct to the more detailed crevasse studies undertaken by Project 5 Part I.

b. In order to lay the groundwork for this project, several preliminary but necessary surveys were undertaken. In order to provide control for both this project and Project 5 Part I, it was necessary to carry a traverse out on to the ice cap from the margin. In order that the traverse have proper azimuth orientation, accurate sun azimuths were necessary. Once control bench marks had been established along the traverse, it was possible to provide the necessary control for either plane-table mapping of small crevassed areas, or for overall aerial photographic coverage.

c. The establishment of this control traverse and its utilization for more detailed work was carried out during the central portion of the work season, within the limitations of the weather.

2. Traverse

a. As originally planned, it was hoped to carry the traverse from the edge of the ice to Morris Station. It soon became apparent in the season that succession of storms and white-outs would not permit it to be carried that far. However, with considerable difficulty it was carried out as far as Camp Whitehorse (37.75 miles). The starting point for the traverse was the new north base point of the new baseline established for the movement stake survey on the ramp. The traverse was carried out with true azimuth, obtained from sun observations made at the north base point, and referenced to "P" Mountain. Distances were read both direct and reversed and on both foresight and backsight as was the case also with angles. Distances were obtained with a theodolite and read to the nearest second. Accuracy should be well within one part in 2,000 to 3,000. The stations are being computed as latitudes and departures and accumulated to rectangular coordinates.

b. At approximately 2½ mile intervals beginning at a point five miles out on the trail and terminating at Whitehorse, sets of semi-permanent bench marks were placed along the trail. These bench marks consist of 2 x 4 timbers buried in the snow, with at least 6 to 8 feet above snow level. They are painted orange and black, and approximately every other set is a pair from which an azimuth can be determined.

c. When the traverse is computed and plotted it will be possible to construct a map of the TUTO-WHITEHORSE trail which will depict all courses along the trail itself, the surface contours for a short distance back from the trail, and the crevasse patterns which cross the trail and have been located by probing and marked. It is certain that there are many other crevasses crossing the trail which have not been marked, but all of them are small, and only would become evident in a year of heavy ablation.

3. Photogrammetric Survey

a. Because of the delay caused by bad weather, the traverse was only finished late in the season. It was considered of vital importance, and got first priority. However, before the traverse was finished, its stations served as control for the anticipated aerial photography requested for the area. The semi-circular ends of Atwells, secured temporarily from the surplus stock at Camp TUTO, were spread out on the snow at 5 mile intervals out to mile 44. These could have been picked up in the aerial photographs and made it possible to tie down the pictures for compilation. Unfortunately, weather and other conditions were not suitable, and the aerial photography was not accomplished. However, the traverse served as control for a second type of photography.

b. At the end of the season, in order to accomplish as much mapping as possible, a series of ground stations were occupied by camera and a series of photographs made from which directions can be determined for sketch mapping of the area between mile 9 and mile 20. These ground camera stations were tied in to the traverse control, and will permit sketch mapping which should give a reasonably accurate picture of the crevasse pattern in the area covered.

c. The area along the trail which is most heavily crevassed lies between about mile 7 and mile 20. It is anticipated that in the future it will be most profitable to concentrate on this area rather than others less well crevassed. This does not apply to the heavily crevassed zones more distant from the trail in discharge areas further down Blue Ice Valley, down the Petowick Glacier, or down the numerous discharge channels feeding into Dedodes Bay.

d. One helicopter flight was made use of later in the season to get high obliques to supplement the ground reconnaissance, and ground photography.

4. Crevasse Movement

In order to get a better picture of the nature and magnitude of movement of crevasses along the TUTO-MORRIS STATION trail, a number of movement stakes were put out across all major marked crevasses. These stakes were placed 30 to 100 feet clear of the trail, and were placed on opposite sides of the crevasses. The distance between each pair of stakes was accurately taped. It is hoped that by re-measuring these stakes next season it will be possible to determine which crevasses and which parts of the ice cap in this vicinity are undergoing the greatest amount of deformation. Though these movement stakes are not intended to give absolute movement, except where they can be tied to traverse bench marks, they will give a very good picture of relative crevasse movements.

5. Conclusions

a. When adding up what was done at the end of the season and weighing it against what was planned for the season, it is felt that actually a great deal more was accomplished than first appears on the surface. The traverse will serve as a key control net which will benefit both the present project and its continuation in the future, but has already been used to tie the Blue Ice project to the edge of the Ice Cap. In the future it should prove of insstimateable value in tying down any aerial photography accomplished in the area. It will further more give a picture in the future, when re-surveyed, for absolute movements in this portion of the ice cap margin.

b. The most consistent problem throughout the entire summer has been the weather. By checking back through my journal I find that we were be-set by nine storms of sufficient magnitude to be classified as such. Out of a total of seventy-six days during the season, thirty-three were either heavy storms or white-outs. It is impossible to survey when you can't see a thing.

c. I want it understood that I'm not offering stormy weather as an excuse for the summer's showing. As a matter of fact, I feel that we have accomplished a large part of our mission for the summer in spite of the weather. However, better weather would have made it a lot easier.

PRELIMINARY REPORT
Project 5.2.1 (Special Report

PROJECT ENGINEER: Barry C. Bishop

1. Introduction

a. The purpose of the 1955 field program was to continue the investigation initiated in 1954 in the TUTO region. Two intensive study areas were selected: (1) The irregular morainel expression immediately north of the TUTO Ramp, and (2) the "simple" multiple moraine expression across the North Star River from "B" Site Landing Strip. A general reconnaissance program was alse conducted along the ice margin-shear moraine area between the Moltke Glacier and the Petowik Glacier.

b. With the very able assistance of Charles Wilson, and the occasional aid of Fred Small and Private John Franklin (1st EATF), the following field study was carried out between 20 June and 19 August, 1955.

2. Movement Study

a. On the ice margin South-southheast of B-Site, an ice movement network was installed. A base line was laid out in the area between the B Site road and the North Star River. A 20 stake movement network, located on the ice margin one mile to the east was tied into the baseline and the network surveyed at the beginning and the end of the season.

b. A six stake movement study was carried out in the area of a prominent shear plane two miles south of the movement net, and 300 yards inland from the eastern most moraine ridge.

3. Ablation Study

a. An ablation study was carried out on the irregular moraine at Camp TUTO, to determine the amount of melt occurring under a blanket of morainal debris during the ablation season. Forty-one hardwood dowels were strategically placed in the moraine and melting of ice was measured as a function of: (1) degree of slope, (2) orientation of slope, and (3) thickness of debris.

b. Several dirt mounds were measured and photographed over the period of the field season to determine the rate of debris accumulation and moraine formation.

c. The rate of slumping was measured by photogrammetric means on a slope with the maximum angle of repose in the TUTO area.

4. Stratigraphic Sections

a. An attempt was made to record the stratigraphic sequence of shear planes exposed in cliff faces in the B Site area. This study was not completed due to a rock fall.

b. A cross section was taken in the 500 foot ice tunnel in the TUTO moraine

5. Profiles: Two profiles of the moraine expression were made in the B Site area to exemplify type examples.

6. General Reconnaissance

a. With the use of a weasel, reconnaissance geology was carried out over the shear-moraine zone between the Moltke and Petowik Glaciers. Emphasis placed on ice structure and geomorphologic processes.

b. Structure: The dip and strike, plus the tectonic espressions, of the foliation and lineation of the ice in the marginal zone were investigated. Differentation, and location of the contact, between superimposed ice and glacial ice was attempted.

c. Geomorphologic Processes: Slumping and sliding of debris on moraine slopes, and the formation of dirt mounds and moraine ridges was studied. The effect of fluvial erosion on the formation and alteration of the moraine topographic expression was investigated. The extensive ice cliff area was studied, with relationship to bedrock topography, drainage, and ice structure. The presence and location of pattern ground and plant life on the moraine was recorded, in relationship to the above processees.

7. Photography: A complete photographic coverage of the project was carried out. Aerial pictures from a helicopter were taken of significant features. Panoramas of the ice margin were taken from "P" Mountain, North Mountain, and the road two miles west of the ice cliff area.

8. Remarks

a. As the ablation season developed one month earlier than the previous season, the project lost some of its effectiveness by not being able to get into the field until late June.

b. The project leader feels, upon preliminary study of the data gathered that: (1) The expression and behavior of the marginal zone correlates with the bedrock map prepared by David Barnes in 1954, and (2) that there are at least two cycles of moraine formation represented in and along the marginal zone.

c. The final report on "Shear-Moraines in the Thule Area, Northwest Greenland", based on field observations from the summers of 1954 and 1955, will be submitted to SIPRE in November, 1955.

Annex E

PRELIMINARY REPORT
Project 6 (Trafficability)

PROJECT ENGINEER: A. A. Rula

1. Introduction

a. The Trafficability, vehicles on snow, program for the summer of 1955 was conceived as a mobile swing of rubber-tired and tracked vehicles whose performance was to be examined under varied snow conditions.

b. This objective was assumed by Waterways Experiment Station with the assistance of a meteorologist from Snow Ice and Permafrost Research Establishment. The personnel consisted of nine civilian researchers and seven enlisted men of the 1st Engineer Arctic Task Force.

2. Objectives

a. To determine the performance characteristics of a representative range of self-propelled rubber-tired, tracked, and towed vehicles on various snow surfaces. The snow conditions which will permit each vehicle to travel at least 10 passes will be determined. The snow conditions will be expressed in easily measured units (cone index, Ramm hardness number, taper, and shear vane indexes, etc.). which will show definite differences between trafficable and non-trafficable snow for each vehicle tested.

b. To develop load towing capacity - snow condition relationships for each vehicle.

3. Procedures

a. The following vehicles were tested during the summer:

(1) Wheeled vehicles

(a) Le Tourneau rubber-tired tractor (18:00 x 25 tires)

(b) M 47 2½ ton truck (9:00 x 20 tires)

(2) Tracked Vehicles

(a) M 29c Weasel

(b) Tucker Sno-Cat Model 743

(c) M 76 Otter

(d) D-6 Tractor (Modified with 30 inch pads)

(e) LGP D-7 (Low Ground Pressure Tractor)

(3) Sleds

(a) Ten ton capacity sled with 24 inch runners loaded to 50 and 100 per cent of capacity. (Total length of runner was 112 inches.)

b. Single self-propelled vehicles tests were conducted with all the vehicles listed above, while only the M 29c, M 76, MD-6 and LGP D-7 were utilized in drawbar tests. The mechanical condition of the 743 Sno-Cat was considered to be so critical that no drawbar tests were attempted. This decision was based on the urgent need for a mobile instrument vehicle such as provided by the Sno-Cat. The wheeled vehicles, except for one particular snow condition, had great difficulty operating even without towed loads. Consequently, the emphasis was placed upon defining the conditions for single operation. The M 47 (2½ ton truck) was operated at various tire pressures and at several percentages of the rated load capacity, while the LeTourneau dozer was tested only at the lowest practical tire pressure.

c. The 10 ton sled was evaluated in terms of the static force required to cause the sled to begin sliding and the kinetic force required to maintain a constant velocity. The values determined were expressed as coefficients of sliding resistance (towing force divided by the normal load). The sled was also tested at several gross loads during the course of the program.

d. A numerical breakdown of the tests is as follows:

VEHICLE	SINGLE SELF-PROPELLED	DRAWBAR	SLIDING FRICTION
LeTourneau	1	0	0
M 47 (2½ ton truck)	6	0	0
M 29c (Weasel)	8	11	0
M 743 (Sno-Cat)	5	0	0
M76 (Otter)	8	5	0
MD-6	14	6	0
LGP-7	9	2	0
10 Ton sled	0	0	14
TOTALS	51	24	14

e. Operations were conducted on both wet and dry snows. All tests from the edge of the TUTO ramp to and including Mile 70 were conducted in wet snow, the remainder were conducted in dry snow. Within each category considerable variation was noted. The snow at Mile 0 was very wet, almost to the point of satuaration, while at Mile 70 it was only slightly moist. Throughout the entire distance traveled from Mile 0 to Mile 220, the general tendency was for the crystal size to become smaller and densities to become lower. Ice lenses were encountered in varying sizes as far as Mile 122. Several times during the course of the program new snow accumulations were added to the surface of the ice cap. The following table lists data pertinent to the top foot of virgin snow as encountered at each test site:

Mile	Crystal size-mm	Density gms/cc	Wetness	Hardness	Remarks
0	2-8	0.45	Saturated	Soft	Glacial ice at 12 in.
7	2-8	0.45	Free water	Soft	Numerous ice lenses
8	2-6	0.48	Wet	Soft to medium hard	Numerous ice lenses
32	2-6	0.50	Wet	Hard to very hard	Numerous ice lenses
60	1-2	0.32	Moist	Soft	
70	$\frac{1}{4}$-$\frac{1}{2}$	0.30	Moist	Soft	Few ice lenses, 2-4 inches new snow
122	$\frac{1}{2}$-1	0.30	Dry	Very soft	Numerous ice lenses
150	$\frac{1}{4}$-$\frac{1}{2}$	0.25	Dry	Soft	
220	$\frac{1}{4}$-$\frac{1}{2}$	0.25	Dry	Very soft	4-6 inches new snow

4. Findings

a. The statements made in the following paragraphs are based on a preliminary examination of a large volume of data collected. The analysis presented herein is therefore to be considered tentative and further analysis may warrant changes.

b. The primary purpose of the single self-propelled vehicle tests has been to gain additional basic information concerning the changes in physical and mechanical snow properties which occur in various types of snow as a result of vehicular traffic. The physical and mechanical snow properties, believed pertinent to snow trafficability were measured utilizing a wide variety of instruments. The measurements made with these instruments show an orderly change in snow properties with respect to the number of passes applied. The strength and density of all the snow types tested increased under the application of traffic. The magnitude of the change was dependent upon such factors as the weight of the vehicle, number of passes applied, and the type and wetness of the snow.

c. It appears that the strength changes caused by a given vehicle can be correlated directly to the results of the remolding test. The large amount of data representing the details of the progressive change of snow values and the interrelationship of the various types of measurements has not yet been subjected to final analysis.

d. Tests to determine the drawbar pull-slip of three vehicles (M 29c, M 76, and MD 6) were conducted on a representative range of snow conditions. The LGP D-7 tractor was tested only at one site because of the lack of a suitable load vehicle. The maximum drawbar pull resulting from each test was converted to a traction coefficient based on the gross weight of the vehicle. All vehicles were able to develop greater traction coefficients in wet snow than in dry snow; however, the maximum drawbar pull occurred at higher percentages of slip in the wet snow. Except for the LGP D-7 tractor, the M 29c usually was able to develop the greatest tractive coefficient in a particular snow condition averaging almost 20 percent higher than either the M 76 or the MD 6. The LGP D-7 tractor was slightly superior to the M 29c on the basis of several tests at one test site. The following table compares the tractive coefficients and percentages of slip obtained for three vehicles at representative test sites. The table shows the superiority of the M 29c in dry snows.

		VEHICLE					
		M 29c		M 76		MD 6	
Mile	Snow Type	T.C.	Slip %	T.C.	Slip %	T.C.	Slip %
32	Wet	39	25	36	60	41	18
70	Moist	43	25	37	40	37	15
150	Dry	38	20	27	35	24	14
220	Dry	33	20	26	33	24	15

e. A comparison of the drawbar pull developed by a particular vehicle with some of the measured snow properties reveals that a definite relationship exists. Examination of the data indicates that a combination of cone index and remolding test measurements made in virgin snow can be used to predict the amount of drawbar pull a vehicle can develop. Some of the other measurements of the physical and mechanical properties of the snow appear to be applicable also; however, sufficient time has not been available to relate snow characteristics and the dimensions of the several vehicles to their towing ability.

f. The results of the sled towing tests indicate that the towing resistance of a sled in dry snow is approximately double the towing resistance in wet snow. Furthermore, a sled towed across virgin snow required about 20 percent greater towing force than the same sled towed over snow compacted by the towing tractor. A similar analysis was made on a two sled train towed behind a LGP D-7 tractor. The second sled, sliding in the runner tracks of the first sled, required approximately 30 percent less towing force than the first sled. The average coefficient of sliding friction for all tests on dry snows was 0.14. The average force required to start a sled moving ranged from two to three times that required to maintain a constant velocity.

g. A good relationship has been shown to exist between the results of cone index and remolding tests on virgin snow and the sliding resistance of the sled. Although these correlations have been based on the results of tests conducted with only one sled type, it is believed that similar relationships can be shown to exist for other types of runners and a range of sled loads.

5. Problems Encountered

a. Performance of rubber-tired vehicles was not carried out as contemplated because:

(1) The LeTourneau dozer, due to the late departure and unseasonably warm weather, impeded travel of the swing when towing through wet, rotten snow and was returned from Mile 10 on 4 July.

(2) The exchange of LGP D-7 for a D-6, mounted with 30 inch pads, necessitated leaving a 10 ton sled, loaded with an M47 (2½ ton truck), at Site Two.

b. The sled test conducted included only the 24 inch runner with the load limited to 5 tons because of the inability of the available prime mover to tow a heavier load over virgin snow. More tests are being made to cover this deficiency.

c. Logistical difficulties were encountered in obtaining the necessary equipment and supplies in time for the scheduled departure of the project.

(1) Approval of Greenland Engineer Activities and detailed coordination with the Commanding Officer, 1st Engineer Arctic Task Force on project requirements could well be implemented at an earlier date. Such a course should assure smooth operations in the future.

(2) Rotation of 1st Engineer Arctic Task Force personnel should be so implemented that a sufficient number of experienced officers and enlisted men are retained from year to year to assist new personnel in learning their job without completely stopping operations.

6. Conclusions

a. On the basis of the preliminary analysis, the following conclusions are offered:

(1) All snow conditions encountered by Project No. 6 in Greenland in 1955 were trafficable to tracked vehicles towing no load.

(2) Rubber-tired vehicles of conventional type had great difficulty operating on snows that presented no difficulty to tracked vehicles.

(3) The tracked vehicles tested were able to exert a drawbar pull ranging from 25 to 40 per cent of their gross weight.

(4) Tracked vehicles were able to generate a greater drawbar pull on wet snow than on dry snow but slip was also greater in the wet snow at the maximum drawbar pull exerted.

(5) The M 29c and LGP D-7 tractor were able to pull greater loads relative to their gross weight than the M 76 and MD 6.

(6) The superiority of the M 29c and LGP D-7 tractor were particularly evident in dry snow.

(7) The coefficient of sliding friction of a 10 ton capacity sled with 24 inch steel runners ranged from about 0.06 to about 0.17.

(8) The sliding resistance of the test sled was greater in dry snow than in wet snow.

(9) The second sled in a train required about 30 percent less towing force that the first sled.

(10) The results of snow measuremente made in virgin snow can be correlated with vehicle and sled performance. It is therefore believed that it will be possible to predict vehicle and sled performance from a few simple snow measurements.

7. Recommendations: On the basis of the preliminary analysis, the following recommendations are presented.

a. Since the results of vehicle tests conducted in Greenland during the summers of 1954 and 1955 have indicated that the Greenland snows can be considered trafficable to the presently available tracked vehicles and not for conventional wheeled vehicles, trafficability studies in Greenland should be discontinued at the present time. Snow trafficability studies should be continued in the States in order that the proper instruments and techniques can be developed and refined to predict the performance of vehicles on all types of snow. After the above has been completed, then a test team should return to Greenland to evaluate the findings.

b. Conventional wheeled vehicles should be considered impractical for use on snow in Greenland, but new types should be tested as soon as they become available.

c. All types of vehicles likely to be used in arctic operations should be tested to determine their performance characteristics.

Annex F

PRELIMINARY REPORT
Project 7a (Pathfinding)

PROJECT ENGINEER: John W. Cox

1. Scope: The work under this project included ice cap tests of:

   a. Pathfinder equipment installed in a modified weasel.

   b. Gyro compass for Combat Vehicles.

   c. Navy Mark 23 Gyrocompass

2. Accomplishments

a. Preliminary tests of the Pathfinder Equipment in a modified weasel were conducted at Camp WHITEHORSE and in the vicinity of Fist Clench (Site Two). Premature failure of the differential drive pinion (in both vehicles) which furnishes distance information to the Vehicle Position Indicator prevented complete test and any extensive use of the equipment as planned. The drive pinion is similar to those used successfully in several other vehicles but in the weasel the pinion is contained in an outrigger cap on one of the differential shafts where lubrication is inadequate. The lack of lubrication combined with the relatively heavy load imposed by the VPI resulted in failure within a few miles of operation. Replacement parts have been obtained and supplementary oil cups or grease fittings will be applied and tested by WHITEHORSE personnel later this season if time permits. With regard to the modified weasel, it was found to be convenient and adequate for the installation of the equipment and for the work of the navigator. However, the added weight of the modified body resulted in sluggish operation and excessive wear and/or failure of power train, engine and suspension components. Although this vehicle was unsuited for the long range operation required as a Pathfinder Vehicle, it should be noted that similar vehicles were used very successfully by other projects (7b and 8a) as mobile test labs, where only short range operation from the test site was required.

b. The gyrocompass for Combat Vehicles was extensively tested to determine both its static and dynamic characteristics at high latitudes. It was used as the sole navigation device in a 1100 mile, round trip test run from Camp WHITEHORSE to Point Dizzywheel (Lat 80° 00' 30" N, Long 44° 25' 00" W). The last 205 miles of the run was made by steering a 5° course according to the compass. The position which should have been reached by this dead reckoning method was compared with the position actually reached as determined by sun observation. This comparison showed that the compass error, <u>plus</u> the human error in steering of the vehicle amounted to less than 0.8° for the 205 mile course. Individual comparison of compass heading with sun azimuths taken along the route indicated that the high latitude performance of the Gyrocompass for Combat Vehicles equals that of the larger, more complicated Miniature Gyrocompass.

c. Test of the Navy Mark 23 Gyrocompass, a standard marine compass roughly comparable to the Miniature Gyrocompass in size, showed that the Mark 23 is not capable of withstanding the violent angular rates and acelerations encountered in a weasel while operating over a rough trail. Installed in the same test vehicle as the Gyrocompass for Combat Vehicles, the Mark 23 acquired at least a 10° error in 15 miles of operation and the azimuth servo failure alarm came on six times indicating that the capabilities of the azimuth servo to follow had been exceeded.

3. Obstacles: A major obstacle to testing which required the long distance operation of vehicles was the lack of spare parts for preventive maintenance and for repair of trail failures. Non-availability of spare tracks made it necessary for the test party to abandon one weasel some distance out on the cap when it broke a track. ERDL requisitioned many spare parts for vehicles in February of 1955, but none were received in time for use this season. It is understood that the 1st Engineer Arctic Task Force placed a similar requisition at about the same time with similar results. The only solution would appear to be still earlier requisitioning of required spare parts.

4. Recommendations

a. It is recommended that in view of the excellent performance and advantages of the Gyrocompass for Combat Vehicles compared withthe Miniature Gyrocompass, the scheduled work directed toward substitution of the smaller compass in the Pathfinder Vehicle be carried on with a high priority.

b. It is also recommended that a suitable quantity of Gyro Compasses for Combat Vehicles be procured for test and use of the 1st Engineer Arctic Task Force during the summer of 1956. It is pointed out that this procurement must be initiated immediately in order to insure availability for the next season.

5. Summary: The excellent performance of the Gyrocompass for Combat Vehicles was, of course, the outstanding result of the seasons tests. There were several other features of this device which should be mentioned. One, battery power drain is very low making it possible to leave the compass turned on for several hours with the vehicle engine shut down without discharging the battery. Two, preheating time is reduced to about ten minutes. Three, leveling stabilityis improved so that, if the heading of the vehicle is known, the compass may be started

and settled ready for operation in about fifteen minutes. These features plus its small size and simplicity make it very well suited for application to tractors, weasels or other vehicles for dead reckoning navigation or trail fellowing on the ice cap.

PRELIMINARY REPORT
Project 7b (Trailmarking)

PROJECT ENGINEER: Ernest H. Wells

1. Introduction

a. Trailmarking project operated in Greenland from June 8 to August 25, 1955. This program was for the purpose of field testing and evaluating means of trailmarking and to obtain information and data for further development.

b. Contract number DA 44-009 ENG 2560 was awarded to General Mills, Inc. of Minneapolis, Minnesota to design and build two new trailmarking receivers suitable for field testing on the Ice Cap using both electrostatic and electromagnetic pickup. Four contract personnel were at Camp Whitehorse for two months taking data on electrical properties of transmission lines in ice and snow, and especially, the two wire trailmarking system. Since the electrostatic field between the wires had been used last year in preliminary work, it was the first method to be tried this year. It was found that the signal pattern across the trail changes with snow depth. This is undesireable and a better system was sought for. Experimental data showed that the magnetic field surrounding the wires was of sufficient magnitude to be used. Work was started on a system of trailmarking using the magnetic fields surrounding the energized wires. This system was proved to be very much superior to the electrostatic method and has been used and successfully tested for operation. The magnetic field is less seriously affected by snow depth over the wires and gives a more consistant field of operation as the line sinks deeper.

2. Accomplishments

a. In an attempt to find a simpler, less expensive solution for marking long distance trails on the Ice Cap, the single line magnetic field system was developed and field tested. The system consists of a single wire, fed with audio power at or near the center point to electrically energize it. A receiver with loop antennas pick up the magnetic field and gives an indication of cross trail position on a light panel in front of the driver. As an added feature, a meter was added to the indicator panel to give the driver, vehicle heading information. When the vehicle is traveling parallel to the wire, the meter reads in the center. Turning the vehicle at an angle to the wire gives a reading on the meter in the same direction as the turn. The same receiver can be used for two wire or one wire trails. The two wire trailmarking was completed from Camp Whitehorse to MORRIS STATION. This completes the necessary wire for a trail through the marginal zone (mile 4 to mile 59.9).

b. A demonstration was held at Camp Whitehorse on 5 August At this time, Colonel Clark, Commanding Officer of the 1st Engineer Arctic Task Force and Colonel Slaughter, Commanding Officer of the Transportation Arctic Group, witnessed the operation of the magnetic single wire system. The system has been much improved since then. With the two wire system a limited number of blinker lights can be used also. Voice communication has been achieved over the two wire and single wire systems using the same receiver, with the vehicle in transit.

c. In connection with the program to evaluate radar as a trailmarking aid, the Raytheon Model 1500 Pathfinder radar set was chosen. This set was first installed on the shop wannigan at Camp Whitehorse for preliminary tests. From this position (900 feet from the trail) the ruts in soft snow were plainly visible after a Poleaxe passed, for at least three fourths of a mile away to determine the resolution. Trail barrels were visible at one half mile toward MORRIS STATION and Camp TUTO. Beyond these barrels the trail went over hills and beyond the line of sight of radar range. In order to obtain better information, the radar set was mounted on a modified wease. On a straight section trail, the barrels were visible for three miles or more.

d. In regard to weather, two Phase II storms were used to determine if any noticeable difference in signal pickups could be detected. White-outs and falling snow did not give a return on the radar and known targets were apparently as strong as they were during clear weather. Some ice mounds and snow drifts show up as bright spots on the screen. Snow covered hills give a blurred return pattern. Weasels have been detected up to and beyond seven miles but no opportunity was found to determine the extreme range that various vehicles can be detected. Men have been detected at 3/8 mile by the zippers in their clothing and the coins in their pockets. Operation on the weasel was satisfactory and the weasel has been run approximately 130 miles since radar was installed without damage to the set. Power was supplied by a 1½ KW Homelite generator.

3. Obstacles

Vehicular failure and the scarcity of spare parts were the most serious obstacles to the operation. Loss of time due to weather and the after effects amounted to almost two weeks total. Another weasel was badly needed for making long line tests over the 60 mile trail, and obtaining line performance data.

4. Recommendations

a. It is recommended that further work be carried on with a high priority to make the single wire system and the two wire system as practical as possible. Considerable design and development will be necessary on the systems and components so that trails and receivers can be designed for vehicular operation.

b. Radar tests be continued and a new radar equipped vehicle be built for complete trail runs during the 1956 season. Radar pictures should be made of the trail so that each section of it can be compared with the radar screen for comparison and location.

5. Summary

a. Successful tests have been run with the single wire trail marking system using the magnetic field and loop antennas. With lights to indicate the safe trail center and a meter to indicate vehicle heading, this system appears to be very practical to the arctic trail marking problem. The receivers can be designed very compactly and with a reasonable battery power requirement.

b. The modified weasels are heavier and more sluggish than the original vehicles, but they have been very successfully used as instrument and test vehicles.

c. The Ice Cap offers great possibilities for radar operation. Some reasons are:

(1) The snow surface gives practically no return compared to land or rough water.

(2) Short range, light weight radar sets appear to be practical for use in special search or rescue vehicles.

(3) Arctic weather conditions give little or no return on 3.2 centimeter wave length radar. Operation in any type of weather should be possible. This would only be proven after extensive field tests.

Annex G

PRELIMINARY REPORT
Project 8a (Crevasse Detection)

PROJECT ENGINEER: L. A. Smitherman

1. Scope

The work this season was directed towards testing an experimental crevasse detector and collecting data on several electrical methods believed to be promising either from theory, model studies, or from study of data collected in Greenland in 1954. A limited amount of refraction seismic data was also collected to aid in further evaluation of seismic methods. Data taken in 1954, on a balanced array system (similar in principle to mine detector arrays) indicated that such a system could be employed as a crevasse detector and Southwest Research Institute, built such a system for tests this summer; however, the system did not measure up to expectations. A four electrode system assembled by SWRI personnel at Camp WHITEHORSE, gave such good results that most of their work was directed toward testing and collecting data on this system. It was demonstrated over several crevasses in the TUTO-MORRIS STATION trail. This system has shown considerable promise in model studies at SWRI.

2. Accomplishments

a. An experimental four electrode system was demonstrated to be successful in detecting crevasses and considerable data was taken with variations of the original system so that the principle could be more completely evaluated.

b. A 400 megacycle remote sensitive volume system was tested. Results were not encouraging.

c. Balanced arrays (at 52 and 156 mc.) were tested. Results were not encouraging.

d. Field strength profiles (1.7 mc.) were made. Results were not encouraging.

e. Grid dip antenna loading measurements were made. Results were not encouraging.

f. Shallow refraction profiles were made on and off crevasses small anomolies were observed. The records will be studied at ERDL to determine if they are significant.

g. Varian Associates made attenuation measurements in the microwave range. Present opinion of Varian Associates is that in cold, dry snow frequencies up to 16,000 mc look favorable, but that in wet snow it is doubtful if a microwave detector could operate above 4,000 mc.

3. Obstacles

a. Early snow storms and bad weather hampered outdoor work.

b. Usual vehicular trouble due to lack of parts for Maintenance.

c. Seismic work handicapped by late arrival of special equipment and hospitalization (one man's absence) of refraction seismic equipment operator.

4. Recommendations

It is recommended that the four electrode principle be used in fabricating test models for 1956 tests. The system should be flexible so that more data can be collected on this principle, as its capabilities and limitations are not well enough known at present to warrant design of proto-type models. Data on other methods should be carefully studied for possible alternate methods as a more detailed study of the data may reveal possibilities not apparent at this time.

5. Summary

The 1955 crevasse detection activities were successful. A system capable of detecting crevasses has been demonstrated although the present system will not give depth, width, or snow bridge thickness. The system has been sufficiently successful and is well enough understood to warrant fabrication of test models. Data on alternate systems are available for study and will be evaluated.

Annex H

PRELIMINARY REPORT
Project 10 Part I (Ramp Studies - Thule Ramp)

PROJECT ENGINEER: Thomas M. Griffiths

1. Introduction

a. During the 1954 season glaciological studies were begun on the Thule Ramp under the direction of Dr. Walter Schytt. By far the major portion of last year's work was concentrated on a movement and ablation net on the ramp; temperature studies on the ramp, at Mile 7, and at mile 20; snow, firn, and ice stratigraphy for some distance out from the ramp; and a rather complete set of meteorological data. The results of these investigations will soon be available in Schytt's final report on the project.

b. For the 1955 season it was decided that the most important continuing data could be obtained at a minimum of effort by resurveying the movement and ablation net on the ramp, and remeasuring the thermocouple stations on the ramp, at mile 7, and at mile 20. This would provide valuable data over a year's duration on ice movement for the ramp, seasonal ice temperature fluctuations with depth, and a year's history of accunulation and ablation both at the ramp and above the firn line. Meteorological data would be available from the projects in the vicinity.

2. Temperature Data

a. The ice thermocouple installations on the ramp and at mile 7 were read at the beginning of the 1955 season and at the end of the season. The thermocouple installation at mile 20 was read only once, at the end of the season. These readings were made with the same Weston galvanometer used last summer. In each case the installation was re-secured to poles which were extended in length (height) so that there should be no trouble in locating them next summer.

b. One difficulty should be mentioned. The length of the leads to the deep thermocouples at mile 7 and mile 20 are not long enough to raise the instrument terminals and switch any higher on the pole. Next year it will be necessary since these are both areas of accumulation, to dig down to the switch and terminals in order to read them. It is suggested that next year additional leads be spliced for the whole installation, making it possible to raise the terminals and switch. If this is done, it will be necessary to read the thermocouples with a null-reading instrument rather than with the weston galvanometer. Comparisons between this year's and last year's data has not yet been made.

3. Movement Data

a. At the end of the 1954 season the movement net on the Thule Ramp consisted of 20 one inch aluminum pipes drilled into the ice. This net extends normal to the ramp ice front for a little over two miles inland, and in two separate rows, parallel to the ice front. The pipes were all located at the beginning of the 1955 season without undue difficulty.

b. To obviate the likelihood that the North or South basepoint from which the survey had been conducted last year, had moved during the winter or spring, the base figure was re-surveyed. No shift in relative position was found. The net was surveyed from the base figure at the beginning and at the end of the season.

c. Because of the Transportation Arctic Group sled yard encroaching on the West basepoint since last year, and the old North basepoint is now almost surrounded by the Engineer camp, it was deemed advisable to locate a new base line less likely to be encroached upon. This was done, further west and south from the old baseline, and the new line has been taped and tied into the old base figure by triangulation and leveling.

d. At the end of the season, when it came time for the second re-survey, it was found that three of the original movement stakes had been destroyed by being run over and broken-off. (Nos. 2, 7, and 9). Three others had to be moved, since they were almost melted out of the ice. Next year a good part of the net will have to be drilled in again, since most of them are now melted out to approximately three meters of bare pole.

e. A preliminary examination of partially computed data indicates that ice near the margin of the ramp (stake #1) has moved less than 10cm., while ice a mile or more out from the margin of the ramp has moved three meters or more. (Stake #3 at mile 1 - 3.15 M, Stake #7 at mile 2 plus - 3.44 M)

4. Ablation Data

a. In conjunction with the movement survey, all movement stakes were measured at the beginning and at the end of the season. These measurements, compared with last year's measurements, will give a reasonably good picture of ablation and accumulation on the ramp.

b. Small polar glaciers offer particularly good opportunities to study a regional regime, since they are more quickly effected by short term climatic oscillations than the ice cap. With this in mind at the beginning of the season, a net of thirteen ablation stakes was placed on the small glacier lying on the northeast side of "P" Mountain.

These stakes were placed in a line running down the center of the ice field from head to foot, crossed by two horizontal rows at one-third and two-thirds of the distance from top to bottom. This ablation net was read when first placed and at the end of the season. If read for several more seasons it should give a rather good picture of the local climatic regime.

5. Conclusions

a. All pertinent data for project ten has been obtained, sometimes at the expense of considerable waiting on the weather. Some of the raw data has been computed, but the bulk has only been recorded and anotated. It will be several months yet before tentative conclusions can be reached.

b. Two observations are worth noting. First, the weather has been unusually bad during most of the working season. This has affected the summer's ablation. At the beginning of the work season (mid-June) it was noted that the melt was much more advanced than at the same time a year previous. However, during the remainder of the summer continued storms and cold weather retarded the melt season in comparison with the 1954 season. The figures should reflect these empirical observations. Second, the presence of the experimental road on the ramp and the activities of TRAG assembling sled trains seems to be having an effect on ramp ablation, and perhaps temperatures. Dust blowing across from the road settles on the ice and raises the amount of heat absorption. It is not yet known how great this effect is, but it may be appreciable. It may be necessary in future years to move at least part of the ablation and movement net further south of the road, to serve as a control for those parts remaining in the vicinity of the road.

PRELIMINARY REPORT
Project 10 Part II (Ramp Studies - Nuna Ramp)

PROJECT ENGINEER: Laurence H. Nobles

1. Introduction: The entire program was carried out by a party of three men, consisting of the project engineer and two assistants. The operation cinsisted of three phases, the first two comprise Part II of Project 10 and the third phase comprises Part II of Project 24.

2. Resurvey of the Nuna Ramp: The party traveled from Camp TUTO to NUNA by weasel. Temperatures were measured on all thermocouples installed in the NUNA Ramp and along the NUNA-MORRIS STATION trail, with the exception of the cable at MORRIS STATION which is now buried and lost. A complete re-triangulation of all movement stakes on the NUNA Ramp was completely re-run and closed to bedrock. Routine observations were carried out on ablation and accumulation, snow cover distribution on NUNA Ramp, and condition of Algal pits and other surface features.

3. Resurvey of Moltke Glacier: One man-day was spent in trying to relocate old movement markers on the Moltke Glacier. Only two of the six markers previously set could be located, but these were resurveyed and additional data was obtained for refinement of the baseline.

Annex I

PRELIMINARY REPORT
Project 12 (Surface Snow Studies)

PROJECT ENGINEER: Carl S. Benson

1. Introduction

a. Research on snow and ice in the field and laboratory varies widely in its method of investigation. The purpose of the 1955 expedition into northern and central Greenland, was to treat the snow and neve layers as ordinary bedded sedimentary deposits. This expedition is a continuation of a study which began in 1952. The concept of snow as a sedimentary rock has existed for a long time, however, snow studies from the stand point of stratigraphy and sedimentation are not common. This is primarily because of the transitory nature of snow deposits in the more densely populated latitudes. However, there are several large areas of the earth in which bedded snow deposits are stable and from the surface layers in the geologic sequence. The interior of Greenland, is an excellent example of this.

b. In general the original plans were closely adhered to, and the expedition had gratifying results. A great deal of delay was encountered in the preparatory stages. This delay was primarily in construction of the sleds and wannigans. Building materials could not be drawn on the base; consequently, the dunnage piles served as supply centers. Assistance was cheerfully given by North Atlantic Constructors and the Post Engineers whose efforts we greatly appreciated. Fully one month was spent on preparation and moving equipment to Camp TUTO and weather added to the difficulties in the second week of May.

c. The delay cut into the research program as mentioned below. The scheduled departure was 1 May, actual departure was at 2330 EST on 13 May; the scheduled air pickup near French Camp VI was to be completed by 25 August 1955, it was actually completed on 22 August 1955, at 1540 EST.

2. Research Program of the Expedition

a. Glaciology: Modifications made in the original plans were as follows. The loss of 13 days eliminated the four day stops. This in turn made it necessary to cut a portion of the research originally planned at these stations. The net result was a cancellation of the crushing strength tests on snow and approximately one half of the on sled trafficability. Failure in presenting the proposed clearance requirements to the Danish Government also resulted in a cut in the original plan. Instead of actually following the crest-line, the route was moved slightly to the west. This is unfortunate since the actual crest-line accumulation figures are of interest. However, the tendencies which were obtained are valuable. With several additional check points it will be possible to form an interpretation of variations in deposition over a large segment of the Ice Cap.

b. The stratigraphic studies have provided an unexpectedly good history of the prevailing climate in different regions along the route. The data when completely worked out will provide information concerning the probabilities of favorable or unfavorable operating conditions for transportation, ski landings, construction, and also on the "life expectance" of stations which may be constructed. It is estimated that variation in the location of sites may apply a factor of 2 or 2.5 in the rate of burial.

3. Glaciology Program

a. Three types of stations were planned.

(1) Rammsonde Stations from 2-100 to 5-230 and at each of the 1954 stations from 1-60 to 2-100. These were made at five mile intervals along route. This data has been calculated and the process of integrating the hardness profiles is approximately one-half completed. Nearly 25% of the data has been plotted. A total of 200 Rammsonde profiles were made.

(2) General Pit Stations were made according to plan with slight exceptions. At position 1-50 (MORRIS STATION + 50) a twenty mile side trip was made to the southeast. Two one-day studies were made on this run (station numbers 1a-10 and 1a-20). These stations proved a proposed concept of variation in accumulation near the crest-line between MORRIS STATION and SIERRA. Originally it was planned to make one day stations at 10 mile intervals from the French Central Station (AD-4) to the end point at French Camp VI. The success in stratigraphic correlation in dry snow, the original loss of time, and a fifteen day delay in AD-4 served as reasons to extend the twenty-five mile spacing for one hundred miles beyond the central station. From 5-140 to 5-230, the spacing between stations was ten miles.

(a) A total of 59 pit studies were made. Of these, 26 were four meters, 17 were from two to three meters and 13 were three meters deep. No estimate will be made of the tonnage moved by hand shovels as it may discourage further efforts along this line.

(b) The work accomplished at each station was according to plan, i.e., temperature, density and hardness profiles with detailed stratigraphic descriptions.

(c) The stratigrapnic description was augmented by the technique of photographing thin slabs of the snow cut from the entire height of the pit test wall. Sieve analysis were made at many of the stations from 3-0 to 4-425, and microphotographs of grains from the several screen fractions were made on some tests.

(3) Extended Pit Stations were eliminated, because of the loss of field time, except for the 3½ day stop at 3-0, while Danish clearance was being discussed, and one 2½ day stop at 4-200. Also, sieve analysis were carried on at the General Pit Stations, but not to the extent that they were planned on the extended stops.

4. Preliminary Report on Meteorological Observations

a. The deposition on the Ice Cap is of meteorological origin and the concept of atmospheric deposition applied to the Ice Cap as a sedimentary rock formation will be developed. The meteorological observations form an integral part of the program. Mr. Ragle carried out the observational work and his report follows.

b. Regular meteorological observations were recorded from 14 May to 21 August, 1955. Observations were made on an average of six times daily, i.e., at 0800, 1000, 1300, 1600, 1900 and 2200 hours EST (1300, 1500, 1800, 2100, 0100 and 0400 hours GMT). The instruments were read between fifteen minutes before and fiteen minutes after the hour according to schedules dictated by both work and travel. From 14 May to 4 June, the 2200 hour EST observation was transmitted by radio to Thule, Greenland. Thereafter, an earlier scheduled contact time necessitated a change on the observation transmitted; so from 4 June to 21 August, the 1900 hour EST observation was sent to Thule, and to Sondrestrom, during a period of transmissions to the latter station.

c. With the exception of relative humidity, ordinary synoptic observations were made. These included date, time (EST), pressure, wind, air temperature (dry, max., min.), visibility, and weather at the time of observation which included cloud type and amount, precipitation, obstruction to visibility, etc. In addition and at the same time a continuous self-recording anemometer placed two meters above the snow surface was read for average wind velocity.

d. In general, the weather on the western edge of the crestline was consistantly good, whereas the weather on the flanks both going toward the center and leaving the center was poorer and more variable. During the month of June and the first week in July, the finest weather was experienced. The sun shone brightly, the temperatures were moderate and the wind light. The impression was that during these weeks a high pressure cell, a ridge of high pressure, or a weak gradient was consistantly present over the northeastern sector of the cap producing moderately stable conditons on the western flank. In the last two weeks f July and in the first two weeks of August, the weather became poorer with over-cast skys, low ceilings, poor visibility, and increasing precipitation. These conditions increased when the party turned westward and proceeded downslope. The weather then improved during the latter half of August and except for high downslope winds which increased at night, conditions were good.

5. Atmospheric Refraction and Magnetic Declination

a. Mr. George Wallterstein, carried on these projects as originally planned. It was possible to obtain both the noon and midnight refraction sights at the majority of stations prior to the start of the western leg. Weather seriously interfered with this program after the middle of July. A correction to the available refraction data at high latitudes will result from the program. The magnetic declination work indicated that the WAC sheets are generally accurate, with maximum errors of the order of 2°. Data from these projects will be worked up this fall.

b. Mr Wallerstein, also attempted to do exact positional work on several of the French accumulation markers and at the French Central Station. Exact solutions were used and there was some indication that movement had occurred. The data is not sufficiently worked up to make further comment at this time.

6. Basic Medical Science Research

a. The Basic Medical Science Research program carried on by Dr. Christie consisted of six projects, all of a medical or biological nature. They were:

Project A - Determination of the types of micro-organisms present in the snow and ice of the Greenland Ice Cap.

Project B - Determination of the change in bacterial flora of the nasopharynx of expedition members while isolated on the Ice Cap.

Project C - Determination of the change in bacterial flora of the skin of expedition members while isolated on the Greenland Ice Cap.

Project D - Determination of the amount of gamma globulin present in the blood of expedition members after isolation on the Greenland Ice Cap. (Gamma globulin is considered to contain at least some of the immune antibodies providing protection from infectious diseases.)

Project E - Determination of fungi present in Greenland Ice Cap atmosphere

Project F - Determination of rate of acclimatization of expedition members to changes in altitude and temperature, as evidenced by level of red blood corpuscles and hemoglobin in blood taken at weekly intervals.

b. These six projects were carried out fully as planned, except for certain necessary modifications which made theorectical plans conform to realistic conditions. Evaluation of data and specimens is to take place at Dartmouth Medical School.

c. While on the expedition, opportunities for planning and carrying out five additional projects presented themselves.

Project G - A record of all wildlife observed on the Ice Cap (with identification where possible), giving number or birds or animals seen, their location and direction of travel.

Project H - Inventory of medical supplies and equipment taken on expedition, with record of utilization of drugs.

Project I - Record of such geographical and meteorological data as might be needed to evaluate data obtained for other projects.

Project J - Determination of physiologic response of expedition members to hard exertion at various intervals during the expedition (this information will be helpful in substantiating and interpreting data obtained in Project F).

Project K - Investigation of the etiology of an apparently infectious disease sustained by an expedition member after having been out of contact with possible disease contacts for at least six weeks.

d. These five supplementary projects were carried out fully; evaluation of data and speciments is to continue at Dartmouth Medical School, and in collaboration with faculty members at Dartmouth College.

e. In addition to the above projects, a complete medical history was obtained and physical examination was performed on each member of the expedition before leaving Thule.

f. A complete record of ilnesses and medical consultations was kept on all expedition members.

7. Communications

a. Mr. James Holston kept a complete log of all radio activities including experiments on antenna construction. An operational and maintenace manual is being prepared. In general the radio communications for the expedition were very good. The summary of radio operations was prepared by Mr Holston.

b. The basic purposes for radio communication for PROJECT JELLO were as follows:

(1) To establish a number of communication circuits with Thule, and Sondrestrom AFB, Greenland.

(2) To establish communications with the several military aircraft involved in air drops and the air pickup, for GCA operation of drop and landing procedures.

(3) To establish communications between the advance and rear parties of the expedition during travel.

c. Authority for establishing the several circuits used was given by Northeast Air Command. PROJECT JELLO was assigned the calls BUG DOODLE #1 and BUG DOODLE #2 for voice operations and CP-2 for code.

d. The following frequencies were used for the purposes indicated:

(1) 1742 Kc - Homing beacon for aircraft location of JELLO position

(2) 3067 kc - Interweasel communication and GCA for and landings.

(3) 4575 kc - Daily code contact with Thule and or Sondrestrom for weather information and other miscellaneous traffic.

4724.5 kc Establishing initial radio contact with aircraft; handling extraordinary traffic with Thule and Sondrestrom AFB's

e. In addition to the above mentioned circuits, calls and frequencies, PROJECT JELLO obtained amateur radio authorization under USNEC-100, using the call KG1AG. Actually, this authorization was not granted to JELLO party, but to the author for use on a personal basis. KG1AG handled over 200 incoming and outgoing personal messages for expedition members through other amateur radio stations, notably VE8PF, Royal Canadian Navy, Padloping Island, and W9NZZ, Stan Surber, Peru, Indiana. Frequencies used by KG1AG included the amateur bands 3800-

4000 kc voice and code, and 7000-2300 kc code. In addition to personal traffic, KG1AG sent and received a number of messages directly concerned with SIPRE business. A detailed account of KG1AG activities will be found in a later report.

f. Equipment used by PROJECT JELLO included two radio sets SCR-193-S, installed in weasels #5 and #8. Some accessory equipment was also used, including a Frequency Meter BC-221-Q, Tool Equipment TE-113, and Multimeter TS-297/U. A detailed inventory of equipment used by PROJECT JELLO will be included in the final report.

g. Few major maintenance problems were encountered by JELLO. The most noticable failure was that of the homing beacon, which never functioned successfully in the field, although tested at Camp TUTO, prior to departure from Thule. A copy of the maintenance log will be included in the final report.

h. In addition to the final report, an operation and maintenance manual designed for radio use in Arctic conditions is being prepared. The author feels that there is a definite need for such a manual, since Arctic radio operation depends for its success on adequate information being available to personnel involved. To date, no manual of this kind has been written. Included will be data on antenna construction, emergency maintenance using make-shift tools and parts when necessary, a summary of regular maintenance procedures, a summary of operating procedures for voice and code use, and othermiscellaneous data of use in the field.

8. Trafficability

a. The program on trafficability was restricted to work on the weasels with minimum attention paid to the action of sleds. Several dynamometer tests were made on pulling sleds up the grades near MORRIS STATION and on level stretches.

b. A technique was developed for observing the deformation caused by passage of vehicles. This consists of curring two adjacent pits and trimming them toward each other until a very thin wall stands between them. This wall was shaved to a thickness of approximately one or two cm. as in the case of the stratigraphic photo sections. Sunlight passing thru this thin wall caused the deformation to stand out clearly, for measurement and photography. Mr Skinrood is the author of the report on this project.

c. The aim of the trafficability studies was to determine what relationship exists between the maximum drawbar pull of an M 29c cargo carrier and the density, temperature, and Rammsonde number of various types of snow surfaces. Track depth, air temperature, wind velocity, and sky conditions were also recorded at the time of testing. Photographs of thin snow sections were taken in the track made by a vehicle to ascertain to what depth the snow had been compacted and distorted.

d. Maximum drawbar pull was obtained by hitching one weasel to a second weasel and two loaded sleds and pulling until track slippage took place. A dillion dynamometer was utilized to measure the pull just prior to and just after slippage. Temperature of the snow was measured at depths of 5, 10, 20, 30, 40, and 50 centimeters. Densities were recorded at 5 and 10 cm. intervals up to a depth of 50 centimeters.

e. The photo sections showed that due to the low ground pressure of a weasel, distortion of the snow seldom took place to a depth greater than 50 cm. Preliminary plots of maximum drawbar pull versus the snow properties show that a simple and direct relationship does not exist, but that the properties are interrelated in such a manner as to prohibit the separation of one of them as an independent variable. Future analysis of the data obtained are to be carried out to determine whether a variable can be found which will enable maximum drawbar pull to be predicted without actually carrying out a test.

9. Oxygen Isotope Fractionation Studies

A total of 275 samples were collected for analysis of the O 16/18 ratio. Two hundred and fifty-nine (259) of these were for Dr. Epstein, at the California Institute of Technology, and 16 were for Dr. Emiliani, at the University of Chicago. These samples were taken to ovserve variations in the isotope ratio with elevation, latitude and temperature of deposition. It is also hoped that the results will provide an additional check on the stratigraphic interpretation of annual layers. The final results from this project may be slow in appearing because of the time necessary for mass spectrograph analysis.

10. Pollen analysis

a. During the 1955, field season Mr. Ragle, conducted the study of airborne pollen. Microscope slides coated with a stained glycerine gelatin moisture were exposed to the air in a pollen shelter mounted on the roof of the glaciology weasel. Geographical latitude of exposure differed from 77°00' N lat. to 69°00' N lat., and elevation varied from 200' to 10,150 feet.

b. The purpose of this summer's work is twofold: first, to determine if there is airborne pollen over the Greenland ice cap and, if so, to determine the type and amount of each type; secondly, to attempt to localize the source of the pollen and spores found by studying the meteorological factors contributing to their transport and appearance over the ice cap. Carrying this knowledge into pollen and spore identification within the snow cover would help to determine total regimen and the seasonal deposition as well as the annual deposition.

c. Four glass slides were exposed in a vertical position for a period of about a week and at the end of this period were replaced by clean freshly coated plates and placed in slide boxes for return and study in the United States. A total of forty-nine slides were exposed during the field season on the ice cap and represent a period from 11 May to 21 August. Concurrently, meteorological observations were recorded daily and will be used as an aid in analysis of the pollen spectra.

11. Airborne Fungi

The program on airborne fungi was carried out according to plan as mentioned above (Basis medical science research section "6").

12. Operational Logistics

a. Detailed records were kept on fuel and food consumption with current cargo inventories maintained for each sled and weasel. The fuel consumption of each weasel was measured at the end of every run. It is expected that these figures will show the influence of variations in elevation and sled load. The cargo carried by the expedition varied considerably between resuppy points, graphs will be prepared to show these variations in individual sleds and weasels and for the group as a whole.

b. It was observed that fuel consumption was higher on this expedition than in the past two years. The comparison with 1953 and 1954 is as follows:

1.8 miles per gallon - Party Solo, 1953
1.9 miles per gallon - Party Crystal, 1954
approx. 1.6 miles per gallon - Party Jello, 1955

c. No records were kept for Party Connie in 1952, the figure for JELLO is only approximate and will be computed at a later time. The higher rate of fuel consumption is attributed to operations at higher elevations in combination with heavier loads.

d. A special effort was made to greatly reduce cargo requirements. Assistance along this line was obtained from the Quartermaster Food and Container Institute in Chicago. Strong emphasis was placed on dehydrated and frozen foods. These were effective in reducing cargo weight and provided excellent meals. A highly efficient and popular item was the dehydrated fruit juice crystal. All of the dehydrated foods and the majority of the frozen meals were loaded prior to departure at TUTO, a total of 630 poinds. An additional 200 pounds of frozen meat was taken on at AD#1. This quantity of special food, slightly over 800 pounds, enabled the expedition to operate for 613 man days with the requirements for standard rations greatly reduced. The cargo weight of food required per man per day has not yet been accurately computed. However, it is expected to be well below the figure of 7.4 pounds per man per day which was required in 1954. A rough preliminary check indicated that the figure will be between 2.7 and 3.0 pounds per man per day. It is to be understood that the food cargo weight includes all packing weight.

e. We, who are especially interested in this problem from the standpoint of light-weight logistics for small scientific expeditions feel that much more can be done in the reduction of required cargo and equipment weights, all thru the expedition. This type of research and effort has definitely paid off in our work. The operational range of 250 miles and 25 days between air drops was easily accomplished, a range of 300 miles and 30 days is within the present means and 400 miles and 45 days may be possible with extra effort. The ranges could be doubled if wannigans were exchanged for cargo sleds and tents used for living quarters. Wannigans were used on JELLO because it was necessary to have space for calculating and plotting data and working with equipment. Also, operating conditions were easily met without elimination of wannigans.

f. The wannigans were constructed from dunnage piles at Thule. A light-weight 2 x 2 frame was covered with canvas, scrap cardboard and glass wool formed the lining. These wannigans were satisfactory in every respect. Cooking was done on the Coleman handy gas plant stove and the Coleman two burner stove. Heat generated while meals were prepared was usually sufficient for warming the wannigan. No stoves were burning when personnel were sleeping under any circumstances. This was because of fire hazards and economy of white gas.

13. Transportation: Transportation arrangements worked satisfactorily. The tandem hookup of POL sled with food sleds was exceptionally good. The fuel sleds were designed to haul fuel barrels only and special pintles were installed for towing the Tucker Sno-Cat sleds. Detailed drawings of these modified sleds are being prepared.

14. Preliminary Report on Navigation

a. Positions were obtained using the Wild T-2 Theodolite, Nautical Almanac, and H.O. 214. The location of each station is listed below:

Station	Date	Latitude (N) °	Latitude (N) '	Longitude (W) °	Longitude (W) '
0-4	5/14	76	23	68	00
0-20	5/15	76	29	66	55
0-35	5/16	76	31	66	23
0-50	5/16	76	36.5	65	35.3
MORRIS STATION					
1-0	5/17	76	44	65	22
1-10	5/17	76	48	64	53
1-20	5/17	76	53	64	24
1-30	5/18	76	58	63	54
1-40	5/18	76	03	63	23
1-50	5/18	77	09	62	54
1a-10	5/19	77	01	62	22

Station	Date	Latitude (N)		Longitude (W)	
		°	'	°	'
1a-20	5/20	76	55	62	00
SIERRA					
2-0	5/21	77	13	62	15
2-10	5/22	77	14	61	40
2-20	5/23	77	13	61	01
2-30	5/23	77	11	60	24
2-40	5/24	77	11	59	44
2-50	5/24	77	09	59	06
2-60	5/25	77	08	58	26
2-70	5/25	77	06	57	49
2-80	5/26	77	04	57	12
2-90	5/26	77	02	56	33
2-100	5/27 - 5/28	77	00	56	04
2-125	5/29 - 5/30	77	02	54	31
2-150	5/31 - 6/1	77	03	52	55
2-175	6/2 - 6/3	77	03	51	20
2-200	6/4 - 6/5	77	04	49	36
2-225 - 3-0	6/6 - 6/9	77	04	48	01
3-25 - 4-0	6/10 - 6/11	76	58	46	59
4-25	6/12 - 6/13	76	38	45	42
4-50 AD-2	6/14 - 6/16	76	19	45	06
4-75	6/17 - 6/18	75	59	44	35
4-100	6/19 - 6/20	75	38	43	35
4-125	6/21 - 6/22	75	18	43	25
4-150	6/23 - 6/24	74	56	42	58
4-175	6/25 - 6/26	74	35	42	33
4-200	6/27 - 6/29	74	12	42	10
4-225	6/30 - 7/1	73	51	41	48
4-250	7/2 - 7/3	73	31	41	25
4-275 AD-3	7/4 - 7/7	73	10	41	06
4-300	7/8 - 7/9	72	49	40	45
4-325	7/10 - 7/11	72	28	40	20
4-350	7/12 - 7/13	72	07	39	56
4-375	7/14 - 7/15	71	46	39	36
4-400	7/16 - 7/17	71	25	39	20
4-425 - 5-0	7/18 - 7/19	71	05	38	58
5-20	7/20 - 7/21	71	00	39	40
5-40 ½AD-4	7/21 - 8/1	70	54.5	40	38
5-65 ½AD-4	8/2 - 8/5	70	46	41	38
5-90	8/6 - 8/7	70	36	42	37
5-115	8/8 - 8/9	70	27	43	35
5-140	8/10 - 8/11	70	18	44	33
5-150	8/12	70	15	44	58
5-160	8/13	70	11	45	22
5-170	8/14	70	07	45	44
5-180	8/15	70	03	46	08
5-190	8/16	69	58	46	30
5-200	8/17	69	55	46	56

Station	Date	Latitude (N)	Longitude (W)
5-210	8/18	69 52	47 18
5-220	8/19	69 48	47 40
5-230	8/20 - 8/22	69 44	48 03

b. The steering aids employed (namely the gyrocompass, sun compass and magnesyn compass) worked very well. The combination of gyro and sun compass enabled us to hold a straight course and to gain confidence in knowledge of precession rate in the gyro. During storms and other conditions of poor visibility the gyro was relyed upon completely, with checks from the magnesyn. Not a single move was delayed by weather during the entire 100 days and 1165 miles of survey.

c. The rate of travel was as originally planned. The travel schedule was made to fit the research program. Departure of the first group (navigational and radio weasels) was always delayed until after the local apparent noon sights for refraction and declination were made. The second group (glaciology and maintenance weasels) continued work at one station until the first group had nearly arrived at the next station. The travel schedule was also dictated by the altimetry program. The preliminary report on altimetry was prepared by Mr. Ragle.

15. Preliminary Report on Altimetry

Two Paulin Surveying Micro-altimeters were used during the 1955, field season. Elevations were read every mile beginning at a point 220 miles east of Thule and ending at the pickup point in the vicinity of Victor's Camp VI. Each day's travel was done in the following manner. The first group would start out about four and one half hours before the second group (1130 to 1200 EST) they would read the altimeter every mile and after reaching the next camp site would continue noting pressure tendency. The second group as soon as the first group had left would note pressure tendency until they were ready to leave (1600 to 1700 EST) and then would also read the altimeter every mile. In this way two traverses were run over the same trail and pressure tendencies were noted during the entire operation. Corrections will be made at a later time.

16. Re-Supply

a. The re-supply by air drop worked extremely well, 100% recovery is reported on all fuel and food drops. The type of drop zone utilized underwent a slight process of evolution using Victors system as a starting point. A sketch of the drop zone is included herein.

b. Two rows of flags were laid out parallel with the wind. When winds were shifting during preparation of the drop zone an attempt was made to have any cross wind come from the pilots left if it was not possible to have it exactly in line with the zone.

c. The entire run was controlled from the ground surface. Constant GCA communication was maintained between pilot and the ground. As the pilot approached the drop zone he flew past two rows of flags each spaced 100 feet apart (black flags on the left, red flags on the right). After these closely spaced flags were passed the interval of flag spacing was 0.1 mile. The center of the drop zone is opposite the main camp. Weasels were spaced along the left side of the zone to give the pilot depth perception. Smoke bombs outlined the actual drop zone and gave wind direction.

d. Plan of Air Drop Zone: See figure 9

17. Packaging

a. All of the food to be dropped was packed into 55 gallon drums. The top was cut out of each drum with a torch and four holes spaced 90^o apart were burned into the drum just below the upper rim. The food boxes were then placed in the drum and the cover put on. The drum was sealed by lengths of concrete reinforcing rod which were put through the holes and bent into the center. (see figure 10).

b. Each barrel was numbered and labeled as shown. The AD_3#2 indicates that this is barrel #2 on air drop 3. An itemized list was prepared for each barrel. A complete breakdown of the supplies which were on each air drop was prepared prior to departure. This made it possible to adjust any shortage or over-supply as it arose in the field. Since the initial delay in departure cut 78 man days of food from the program it was necessary to eliminate some of the food from AD 3 and AD 4. The change in course caused by diplomatic clearance also changed some of the re-supply requirements. These changes were easily made with the system of pre-packed barrels. It merely meant cancellation of barrels 3, 4, and 7 from AD 3 and barrels 1 and 3 from AD 4.

c. The preparation of such details on air drop re-supply by the expedition members before leaving the base of operations cannot be urged too strongly. However, it is essential that there be a contact man on the base for the expedition while it is in the field since it is impossible to foresee every detail. The arrangement which was utilized this year with Segeant Kreps of the 1st Engineer Arctic Task Force acting as base contact man worked very well.

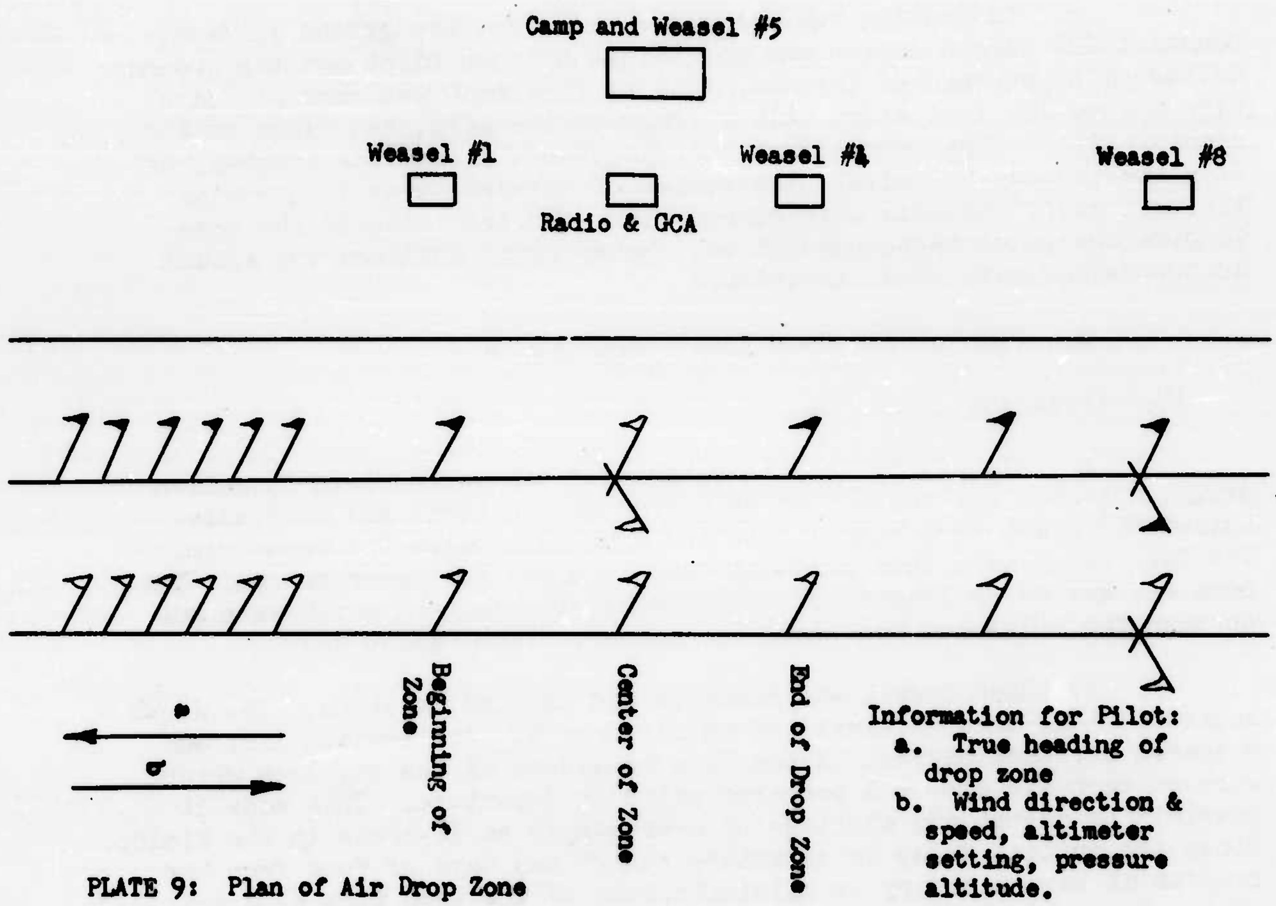


PLATE 9: Plan of Air Drop Zone

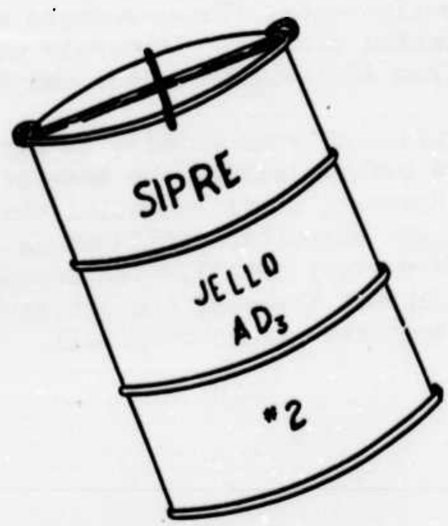


PLATE 10: Sketch of Barrel for Air Drop

Annex J

PRELIMINARY REPORT
Project 13 Part I (Snow Structures)

PROJECT ENGINEER: R. W. Waterhouse

1. Introduction

a. Party arrived at FIST CLENCH (Site Two) on 26 June and immediately went to the work area of the 1954 projects. The Atwell camp was open and operating on arrival which permitted SIPRE personnel to start immediately on research project work.

b. Entrances to both the snow house and the snow laboratory were opened. A Jamesway shelter on piles was placed at the northwest corner of the 1954 area and a 1st EATF constructed Wannigan on a sled was placed at the northeast corner of the 1954 work area. The Jamesway was used for materials storage and the wannigan for a warmup shelter and office. A NS tunnel, to extend from the north end of the snow laboratory was started to eventually tie into the plowed trenches. To the northwest of the 1954 work area, flagged lines EW and NS were laid out, locating the production trenches for the plow work.

2. Accomplishments

a. Repairs were made to the snow house wall melted out last year by the generator exhaust. Two pressure cells were installed, one at either end of a roof beam. Since the snow on the roof was mostly hand placed to eliminate melt leakage, no significant load increase was registered over the time observed. The central column of the snow house was extended using sections of tube taken from the escape hatch which was closed off. The damaged wind charger was removed to be sent to TUTO, for repair and storage. Trench shoring in the NS trench was inspected and three frames at the south end of the trench which had been screwed to panels on the west wall which failed to slide freely with the natural snow consolidation were relieved. Two pressure cells were replaced with Dillon gauges. A U-1 tension cell (Baldwin) was replaced for use with the snow anchors. The replacement was a pressure cell brought from Wilmette for the purpose. All spreador studs were adjusted. Vertical movement between instrumented panels is now possible to gauge by sections of Crisco rod replacement scales permanently installed. Typical pressures as indicated 10 August at the southern end of the panels as follows: Top panel 700#, Middle panel 1730#, Bottom panel 1160#.

b. Necessary tools, fuel, and equipment were left in the snow house and trenches to facilitate pressure observations during the winter if an observer is sent out.

c. Four damaged columns in the EW trench where vertical pressures are being measured, were repaired. The panels over pressure cell 16 (refer to 1954 report) were unlocked from adjacent panels, showing no immediate shift of pressure. New snow gauges were installed over cell 16, 17, and 18. Snow depth and pressures for these cells on August 11, were as follows: 5.2' 3840#, 5.6' 6800#, and 4.55' 5000#. Between August 4, and 11, no snow accumulation or loss was observed, during which period the pressure cells registered the following changes: #16 decreased 197#, #17 increased 85#, and #18 increased 240#.

d. Density of the snow in the vicinity of these roof panels was measured to a depth of six feet to permit more accurate evaluation of the gravity component of pressure.

e. The Peter Snow Millers Senior and Junior arrived at FIST CLENCH (Site Two) on the 10th of July. Shelter for them was erected of tarpaulins adjacent to the wannigan. The report of their performance is to be made by Mr S.R. Stearns, based essentially on his observations. Peter Junior became inoperative before completing the four foot trench work planned, necessitating a change of plans for trench covers as reported elsewhere. Essentially the machines are capable of cutting four and eight foot trenches to useful depths under favorable wind conditions. Modifications are possible to increase their effectiveness. Peter Junior will require extensive modification to be of practical usefullness in this area.

f. According to plan, observations were made on several types of natural snow sections saw and cable cut from the walls of trenches made by the snow millers for the purpose of forming permanent covers for the trenches. Sections utilizing the top three feet of snow can, under favorable conditions serve to cover four foot trenches, either by simple beam action or by cantilever beam action. Cantilever beams having not over 24 inch spans. The preparation of wedge shaped cantilever beams disclosed the fact that for the type of snow available, sliding friction is overcome by inclines of 18° 30' or roughly a slope of 3 to 1. It is strongly indicated that several types of such sections utilizing the top four feet of snow can successfully cover permanently a four foot trench.

g. Circular arcs, with their center of rotation in the plane of the snow surface and outboard from the trench wall one sixth of their radii, rotate freely on being cut free. A 41" radius section rotated into position overhung the trench wall 24 inches.

h. A tapered catilever beam cut from plow disaggregated and blown snow of 30 inches height and 74 inches span, hand cut and pushed into position produced a 39 inch overhang. Properties of the plow disaggregated and blown snow are quite remarkable, high strength and density being typical characteristics, which will be referred to at greater length under reports of Projects 13 Part II and Part III. It was found that the chief factor contributing to failure of such sections for trench covers was support failure due to high stress concentration at the trench wall.

i. The most spectacular of such cover types was a twenty foot section made by Mr. S. R. Stearns, of formed arches over an eight foot trench. The arch form of plywood of 8 foot span had a rise of 12" and was essentially parabolic in shape. Blown snow from the Peter plow was allowed to accumulate to a depth of 30" and age for four days before the plywood forms were removed. These arch sections of snow remained intact and deformed gradually with time. A record of the deformation rate is being made.

j. In the proposal for Project 13 Part I, presented for approval in May 1955, three types of service covers for four foot trenches were discussed in terms of cost, weight and cubage. These covers are not experimental in the sense that they are instrumented or are unstable in any way with a load of snow equivalent to a year's accumulation. Covering the Peter Jr. production trench are representative sections of each of these three types. One of plywood with two by four cross members, another of hardware cloth covered with polyethelene film (.005 thick), both supported on two by four cross members and two by six longitudinal support producing a skylight arrangement. A third type is a special fabrication of corrugated aluminum sheet with slotted aluminum pipe at the supported edges to serve as support to the span whether it is essentially in either compression or tension. A fourth type of cover for a four foot trench covering is experimental and is composed of plywood sections 24 inches deep and cut in the form of arches 8 feet in length. These plywood bulkhead type sections are spaced five feet center to center and covered with hexagonal metal netting which is in turn covered with plastic film. The netting is anchored to the plywood supports along the netting margin, the marginal wires being hooked into slots cut into the arched top of the plywood three feet either side of center. It is anticipated that these deep sections of plywood restrained by hand packed snow at their supports from lateral buckling will progressively be more fully supported against lateral strain by the netting as it is forced to bend over the upper arched edge of the plywood by the increasing snow load.

k. The cable and hexagonal netting trench cover for the eight foot trench was installed without incident. The anchors were placed vertically with a nominal initial load. Snow excavated from the eight foot trench formed a natural barrier to wind drift during a storm which immediately followed the installation and caused deposition of up to 4½ feet of snow on the netting, simulating more than a years accumulation. The netting and cable bellied under this load but neither cable tension nor settlement of the netting were excessive, dangerous or continuous at any high rate. Cable tension was observed for ten days and the lowest point across the span is continuing to be observed for vertical travel. The remainder of eight foot covered trench is spanned with a pitched roof arrangement composed of plywood panels built originally for the four foot trenches.

l. Planned operations for cutting and studying openings in a snow monolith were changed due to a breakdown of Peter Junior and the necessary use of an eight foot trench on one side of the monolith. This eight foot trench required use of experimental covers. Because there was some hazard working under such covers, particularly if their support was in unstable motion, the arch cuts beneath such covers are restricted to two which are as follows. To compare with the eight foot span arch of plow blown snow, an eight foot arch was cut in the monolith, with a three foot depth of natural snow cover at the crown. The displacement both vertically and laterally was measured at three points. A semi-circular eight foot radius arch cut was made and measurements of displacement taken at four points until a displacement of over six inches occurred. Further displacement would have endangered the trench covers and was therefore arrested. This arch cut is related to the size and shape of the Jamesway shelter.

m. Two sizes of snow anchors of 16 gauge steel sheet designed and fabricated at Wilmette, were tested to determine maximum resistance, long time resistance and the increase in resistance due to consolidation of the snow under load. The small 24" anchor, inserted by hand, appears most effective with a positive angle of insertion, (between 5 and 10 degrees; at this angle their temporary resistance has been recorded at over 1000 lbs. These anchors were used for the cable and netting installation over the eight foot trench.

n. The resistance of new surface snow to the penetration under load of various shaped plates was investigated. Plywood plates of 25 sq. inches area of circular, square and triangular shape were loaded by three different methods; application of lead weights by hand simulating 1 psi. and 2 psi.; loading by an impact technique similar to that used for Ramm hardness, and loading the plate by hand thru a reaction frame and a calibrated spring. The latter method being superior as it prevented to a large extent uncontrolled inertial types of pressure applications. The test results show that the circular plate, all other things being equal penetrated 30% more than the triangular plate of equal area, under a load of 2 psi. There is an indication that this difference will increase for particular types of snow. These tests were conducted, and the data will be viewed as a possible aid to the evaluation of the resistance to snow loading of the trench covers and pressure cells in the 1954 installation.

3. Additional Remarks

The physical and mechanical properties of the snow involved in the work cited will be found in reports of Projects 13 Part II and III by T. Butkovich and James Bender. Other environmental factors of value as reported by M. Diamond, of Project 23, logistics and special projects observations, will be reported by S. R. Stearns, Chief of Applied Snow and Ice Branch and also Field Director of the FIST CLENCH Operations.

PRELIMINARY REPORT
Project 13 Part II (Snow Physics)

PROJECT ENGINEER: T. Butkovich

1. Scope

a. The study of the various strength properties of snow, particularly those that appear in the upper layers of snow cover and are of density 0.50 g/cm^3 or less. Various tests were devised to accomplish this, and the validity of these tests was also checked for snows above 0.50 g/cm^3 density, up to 0.75 g/cm^3. A special mechanical loading apparatus with three interchangeable proving rings of 500, 2,000, and 10,000 lbs capacity was designed to impress and measure the ultimate loads required to cause the snow to fail under various types of conditions. This device was used to determine the unconfined compressive strength, both confined and unconfined double shear strength, and ring tension strength. Another apparatus was used to determine the torsional shear strength of the snow.

b. This required the drilling of a fifty-five foot vertical core hole for obtaining specimens from the bottom of the 1954, 100 foot deep pit. These specimens are to be returned to the SIPRE laboratories, Wilmette, Illinois, for studies under controlled conditions of other physical and mechanical properties. All tests were performed on three inch diameter cylindrical cores obtained with a coring auger.

c. Assistance of Project 13 Part I, for determination of physical properties such as density temperature, and Ramm hardness of the snow in the upper layers which would be necessary for analysis of the efficiency of the Peter Snow plows.

2. Measurements Taken

a. Unconfined double shear strengths were measured for snows of densities of 0.40, 0.45, 0.50, 0.55, 0.60, and 0.70 g/cm^3. At least ten specimens for each of these densities were taken to obtain a good statistical mean for each point on a density shear strength curve.

b. Confined double shear strengths were measured for snows of densities 0.40, 0.45, and 0.50 g/cm^3 with lateral pressures of 5, 15, 30, 45, and 60 psi. At least ten specimens for each combination of density and lateral pressure were taken to obtain a good statistical mean for each point on a lateral pressure shear strength curve. Confined double shear strength measurements were also made on snows of 0.55 g/cm^3 densities with lateral pressures of 30 and 60 psi. Here at least eight tests were made for each combination of density and lateral pressure.

c. Ring tension tests were made for snows of density 0.45, 0.50, 0.55, 0.60, and 0.65 g/cm^3. At least ten tests were made for snow of each density. Tests were also made on forty-two specimens taken from the fifty-five foot vertical core hole in the bottom of the 100 foot pit. These densities varied between 0.60 and 0.75 g/cm^3.

d. Unconfined compression tests were made for snows of the low densities of 0.40 and 0.45 g/cm^3. At least ten tests for each of these densities were made. The tests for higher density snows were completed in the 1954 field season.

e. Torsional shear tests were made for snows of densities 0.50, 0.55, 0.60 and 0.65 g/cm^3. At least eight tests were made for each density.

f. Density and stratigraphy profiles were taken to the bottom of the trenches cut by the Peter Senior snow plow. One profile was taken in the NS experimental trench and two profiles were taken in the EW production trench.

g. Ramm hardness profiles were taken to 5 meters near the EW trench cut by the Peter Senior snow plow. One was taken at each end and at the midpoint. Two other profiles were taken near the EW production trench cut by the Peter Senior snowplow.

h. The effects of various pressures on undisturbed snow was measured by introducing static loads to the surface of the snow. Pressures of 0.5, 1.0, 1.5, 2.0 and 3.0 psi were used to show the change in density caused by these pressures and also what depth effect they produced. Density profile was made on the undisturbed snow and also on the loaded portion. Three pits were made for each of the above pressures.

3. Preliminary View of Data Taken

a. The value of the unconfined double shear tests for snow of density of less that 0.55 g/cm^3 is questionable at this point. A high percentage of the failures occurred in single shear with one or more tension breaks for these densities. For snows of higher density a double shear failure occurred as was expected.

b. Confined double shear tests with low lateral pressures (less than 30 psi) at the lower densities of 0.5 g/cm^3 or less produced failures similar to those obtained for unconfined double shear. However, at the higher densities and higher lateral pressure more typical breaks were obtained.

c. These tests proved to be the most reproduceable of all the measurements made. Once a correlation is made between the ring tension and direct tension test, it is felt that ring tension tests will be a valuable field test for determining the tensile strength of snow and ice, because of the ease of preparation and breaking of the specimen, and that only small quantities of the material are necessary.

d. The Unconfined Compression Test is a good field test also, because of the excellent reproduceability obtained, at densities above 0.50 g/cm^3. These tests, as with most other tests, are restricted because of the difficulty in obtaining good specimens of the lower density snows.

e. Values obtained from torsional shear tests were quite uniform and reproduceable. However, these tests require a great deal of time in preparation and are not quite possible for field tests. The helical break that occurs is similar to those obtained for other brittle materials.

f. The study of the effects of various static pressures indicate that an exponential relationship can be drawn for the change in density or psi curve. Also a linear relationship between change in density or depth affected can be drawn.

4. Additional Remarks

The snows in the upper layers are of low density (those in the upper three feet usually have a density of 0.30 g/cm^3 or less). These snows are practically cohesionless and of extremely low strength. The tests used are not adaptable for these snows and as far as engineering needs go, these snows can be considered as having no strength as long as they are not disturbed and compacted to higher densities.

Annex K

PRELIMINARY REPORT
Project 18 Part IA (Patterned Ground)

PROJECT ENGINEER: Jack D.Arthur

1. Introduction

a. Patterned ground is a phenomena peculiar to arctic and subarctic regions. The patterns are thought to evolve by means of sorting caused by the annual freezing and thawing. The patterns formed are usually polygonal in shape with other variation including stripes occupying sloping ground. Many theories have been propounded regarding the formation of these features. Little or no data has been collected regarding soil types, movement rates etc., from which a more correct understanding of the mechanics of movement can be determined.

b. A field party was responsible for locating the features to be studied and this follawed by recording natural field relationships of terrain, soils etc., and nothing specific relationships. All location studies lie within an area roughly bounded by an arc of eight miles radius with Camp Tuto at the center and swung from the edge or the ice cap to the north to a point approximately due west of Tuto.

2. Scope

A disturbed and undisturbed feature were located in the chosen areas. The disturbed feature was excavated while detailed mapping, sampling and photographing was restricted to the undisturbed feature.

3. Personnel

The party was headed by a graduate geolist, a member of the 1st Engineer Arctic Task Force, and asisted by a non-commissioned officer, also a member of the 1st Engineer Arctic Task Force, who served as rodman.

4. Equipment

Either a jeep or a weapons carrier was used to transport the personnel from the camp to the field site. A graphlex camera, 4x5, was used in the black and white photography and a 35mm. Leica camera was used for the color photography. Mapping of th feature was accomplished with a plane table and telescopic alidade using a "Philadelphia" level rod and an aneriod altimeter. Hand excavations were accomplished by means of picks and ehovel or by drilling with a wagon drill, shooting and removing debris by meane of a bulldozer. Taping and measuring during croesectioning and mapping of excavations and trenches was done by means of steel tapee, rules and level rod. A small blackboard was eet in each photograph on which was written pertinent data of each photograph.

5. Undieturbed Featuree

a. A reconnaieeance on foot was made to gather data and record notes which gave a general description of the feature. The boundries of the features were flagged for location and wooden dowels placed around the areae to be eubjected to photographing with the precision camera.

b. A small blackboard was setup within the area of the photograph on which was written specific details of the photo such as; data, feature, number and photo number. The entire feature was photographed to give a low oblique of the area and including cloee-ups ehots of items of specific interest. The sides of the excavations and trenches were photographed to show relationehips between the active layer and the permafrost zone, The photos included both black and color shots.

c. The eurface areas of the undisturbed features were mapped by plane table and teleecopic alidade to give the relief and an area description. The mapping technique involved reading stadia for horizontal distances and differential leveling for elevations.

d. Samplee of the eurface vegetation from the undisturbed areas were taken to record the various types of vegetation. These samples will be submitted to a botanist for scientific classification. This study will probably be expanded next year to include the full time study by a graduate botaniet, These samples were tagged with pertinent descriptione while eome small eamples were placed in sample bags.

6. Disturbed Features

A trench was excavated parallel or at right angles to the surface feature by digging by hand down to the froet table or down below the top of permafrost by means of drilling and blasting. After blasting the loose material wae removed by a bulldozer and the sides of the trench cleaned by means of shoveling and sweeping. Drawings, cross-sections and sketches were made of the exposed sides of the excavations. Differences in soil color, texture, structure, were noted as well as prominent rocks ice wedges and lenses. Except that, where individual stones were in a critical location or showed relationships with encloseing soil which were particularly significant the soil types and structures were illustrated diagrammatically. Individual stones were drawn in place when their commission would materially detract from the value of the drawing. Temperatures of the various frozen and unfrozen ground were recorded.

7. Results

a. Cross sections of twelve trenches and maps of thirteen features were drawn. Approximately seventy pages of field notes were taken.

b. Valuable data on the surface and sub-surface characteristics of various types of patterned ground was obtained. This data when studied and evaluated with soils, movement studies and laboratory examination of chunk samples of permafrost and ice will enable a more thorough understanding of the physical phenomena which causes patterned ground.

c. Above all, the data obtained will provide a basis for a more thorough and exhaustive study in succeeding years.

PRELIMINARY REPORT
Project 18 Part IB (Soils)

PROJECT ENGINEER: Jack D.Arthur

1. Introduction

a. Patterned ground in the Thule Area is presumed to have evolved from the original, predominantly unsorted, glacial debris. The soil particle sorting, surface cracking, preferred vegetative cover, etc.that has resulted in the present patterns was controlled to an important degree by the nature of the original soil. The variation of the physical characteristics of the soil within and across the patterned ground features resulted from the mechanical action that produced these features. It was therefore believed that a study of the physical characteristics of the soil would be important to a better understanding of the mechanics of patterned ground formation.

b. Project 18 Part I came equipped to collect soil samples and to perform some of the simpler soil tests in a laboratory established in Camp Tuto.

2. Scope

a. The mechanical grain size distribution of the soil is considered important for the determination of the frost susceptibility of the soil and the degree of sorting that has taken place in a patterned ground feature.

b. The moisture content of a soil is important because of its effect on thermal properties, vegetative insulation,and its indication of drainage conditions and sources of ice lense formation.

c. The natural density of the soil indicates relative compactness, frost fluffing, and gives an indication of the strenght of a soil in resisting movement.

d. The above determinations all fall within the scope of the soil laboratory work performed in conjuction with Project 18 Part I.

e. As an aid to the determination of the interrelationships between the type soil, nature of ice lense formation therein, direction of ice lense formation forces, percentage of ice in a sample, particle orientation (fabric) etc., frozen ground samples were obtained and carefully stored for shipment and study at the SIPRE laboratories.

3. Personnel

The gathering of samples, testing or preparing samples for storage and shipment, plus the necessary paper work required the full time of one man

4. Equipment

a. A field soil mechanics laboratory was set up in a 18 x 16 foot Jamesway building, erected by project personnel at Camp Tuto, in six man-days of labor. This laboratory was supplied with heat from a diesel fuel stove, running water from a 55 gallon drum siphon arrangement, electricity from a 1½ and 3KW generator.

b. The laboratory was equipped to preform sieve analysis for grain size, moisture contents, and field densities.Adequate storage cans were brought for the purpose of transporting some samples back to SIPRE for any of the more extensive tests deemed desirable.

5. Active Layer

a. Trenches were dug across various patterned ground features, The nature of the soils encountered along the faces of the trench were taken as soon as possible after excavation. The samples were located in plan and section on the trench sketchsheet.

b. The above samples were obtained primarily for grain size and moisture content tests. Samples were generelly teken in vertical or horisontal sequences. Sometimes isolated samples were teken to check local points of interest.

cIn a number of areas set aside for study with precision camera, field density tests were performed on the surface soils to depths averaging about seven inches. Density was obtained by water displacement method using a thin plastic sheet to line excavated hole. The excavated soil was then taken to the project laboratory for moisture content and grain tests.

6. Frozen Ground Samples

a. With the use of explosives, some trenches were cut deep enough to permit the sampling of frozen ground under various types of patterned ground features.

b. Equipment was brought to the site so that frozen grond samples could be obtained, tested for density, and wrapped for storage or further testing immediately following blasting and excavation. Thaw was held to an acceptable minimum by rapid testing, using ice water in displacement volume determination, and immediate wrapping in alumium foil to minimize radiation warming.

c. Samples were stored in the shaded side of the excavated trench until all were taken. Then they were placed in the ice tunnel storage room or a suitable freezer for storage until shipment. It is planned to ship these frozen samples to SIPRE using dry ice cartons.

d.In addition to the soil samples other frozen soil samples were also collected for immediate testing in the project laboratory.

7. Results

a. The results thus far are expressed in terms of the detailed test results thus far gathered.

b. The following indicates the approximate extent of the sample accummlation and testing accomplished:

(1) 200 sieve analysis and water content samples

(2) 30 surface densities

(3) 25 foil wrapped frozen samples

(4) 25 frozen ground densities

8. Conclusions

a. Detailed conclusions must await the assembling and digesting of the data obtained. The data will not be complete until further testing is accomplished in the SIPRE laboratory. Thus, any detailed conclusions are now premature. However, some general observation follow:

(1) The soils lab was adequate for the program. A much larger oven would be very desirable, but only so if a constant source of electricity were available.

(2) Excluding surface gravel accumulation, most soils tested have a high percentage of grains passing the 200 sieve and are definitely frost-susceptible.

(3) There is a general absence of truly plastic (clay mineral) fines.

(4) The surface soils are generally in a surprisingly dense state in view of solifluction and frost heaving.

(5) The density of frozen soil samples varies over a wide range, indicating wide ranges of ice content are possible.

(6) Coarser soil particles (gravel) are cold points and favor local ice lense accumulation on thier surface. This phenomenon may be an important factor in the explanation of the differential movement of the coarser particles.

PRELIMINARY REPORT
Project 18 Part IC (Precision Photography of Surface Features)

PROJECT ENGINEER: Jack D Arthur

1. Introduction

It is believed that the forces which are responsible for forming patterned ground are still active. In some of the area of patterned ground the rate of movement is believed to be such that it could be accurately determined by measuring the magnitude by means of a precision type camera. The camera is able to record movement of at least 1/16" per year. It is planned that this photographing be continued in succeeding years. Since the camera was being used for the first time it was found that modifications are necessary to insure locating the camera accurately.

2. Scope

Various types and features of patterned ground were photographed over as wide an area as possible. Permanent type bench marks were established adjacent to the sites and were used for accurately locating the camera in order that in succeeding years the camera could be relocated over the same features.

3. Personnel and Equipment

The work was performed by a civil engineer and a geologist. The camera was custom made for the specific job, Pollak and Skan, Inc., of Chicago, Illinois, were engaged as consultants for the design data. The camera employed a wide angle lense capable of a coverage of approximately ten feet in width while located approximately ten feet above the ground.

4. Method of Operation

a. During the early part of the work with the camera chaining from the permanent bench marks was used to locate the center point of the area to be studied. This point was located on the ground directly below the optical axis of the lense. Since the ground was not level a plumb-bob was employed to locate the intersection of the arc made in chaining. Due to the wind which prevailed almost every day it was impossible to get the accuracy needed for locating the points within the area to be photographed.

b. A theodolite was later employed in this work. The instrument was placed over each permanent bench mark and a sight taken on the Thule radio tower and an angle was then turned to a fixed point near the lense of the camera. The optical axis of the lense was then located on the ground by depressing the telescope of the instrument to a fixed level plate on the ground. The line of sight for each location was then made by means of sighting-in two points along which a straight line was drawn by means of a straight edge. The intersection of these two lines then formed the location of the center of the lense on the ground. The azimuth of the camera was determined by sighting along the top of the two clamp screws towards the Thule radio tower.

c. A level rod was laid on the ground for the purpose of a scale in the photograph and this was leveled and the elevation of same determined by leveling.

5. Results

a. It is believed that with the present system of locating the camera the maximum accuracy can be obtained.

b. A considerable amount of modification is necessary in order to speed up location.

c. Determination of the accuracy of the lense cannot be determined until the second photographs are taken next year.

Annex L

PRELIMINARY REPORT
Project 22 (Ice Tunnel)

PROJECT ENGINEER: Niles E. Grosvenor

1. Project 22 was 122% complete as of August 15, 1955. This includes a tunnel 500 feet long and a storage room built for Northeast Air Command.

2. Deformation stations were placed in the tunnel and in the room. They were read a nd recorded weekly.

3. The tunnel location was surveyed and tied into permanent bench marks near Camp TUTO. The surface above the tunnel was surveyed to determine the depth of ice cover over the tunnel.

4. This project was possible through the excellent cooperation of the enlisted men assigned to us from the 1st Engineer Arctic Task Force.

5. The tunnel is partially sealed to prevent the inflow of water and will be completely sealed upon the completion of present scientific studies.

Annex M

PRELIMINARY REPORT

Project 23 (Snow Drift and White-out Studies)

PROJECT ENGINEER: Marvin Diamond

1. Introduction

a. Project 23 was divided into two parts, 23.1 and 23.2, the former consisting of snow drift studies, the latter consisting of a study of white-out phenomena and measurements of the heat balance on the Greenland Ice Cap.

b. In support of both of these projects, the following meteorological variables were continuously measured and recorded at five (5) levels above the snow surface:

(1) Air temperature

(2) Dew point

(3) Wind velocity

2. Snow Drifting and Drift Control (23.1)

a. The purpose of this study was to determine the applicability of wind barriers as a means of protecting installations on the Greenland Ice Cap from drifting and blowing snow. A typical wood slat fence of 40% density (ratio of solid to the total area of the fence) which is used extensively in the mid-latitudes was utilized and also a snow wall, four feet high and fifty feet long, was constructed.

b. The snow fences were erected in three parallel rows of 200 feet each, two of the rows being six feet high and the third row three feet high. The three rows of fences were located normal to the prevailing wind, utilizing the three rows as a unit to protect an installation located downwind of the three foot fence. The fences were placed 200 feet apart with the two six foot fences located upwind of the three foot fence. Bamboo poles were placed between two fences to measure the accumulation of snow.

c. An important measurement that had to be made was that of the amount of snow moving in the air parallel to the snow surface. This was accomplished by means of special instruments designed to catch and retain the moving snow. The amount of snow was measured in mass per unit area per unit time (gm am-2 min-1)

d. After the first storm period it was observed that as much snow accumulated downwind of the third fence as accumulated downwind of the first and second fence. The efficiency of this type of fence or the amount of snow the fence retained of the total snow which passed the fence thus becomes an important factor. Measurements of the mass of snow moving through the air in a given time compared to the mass of snow retained by the fence, indicated the fence to be about 20% effective.

e. Since snow which could pass through the fences would be available to drift around any object behind the fences, it was decided to simulate an installation by placing empty oil drums behind each row of fence. The accumulation around the oil drums will be compared for both the protected and unprotected areas. At this time there has not been sufficient snow movement since the drums were positioned to reach any conclusion. Measurements to be made during the spring of 1956 may reveal more information.

f. During the summer season only a moderate amount of drifting snow (that moving along the surface when no precipitation was occuring) was measured. For example during one period, 0.06 gm am-2 min-1 was measured so that the snow moving past an area of the three foot fence (240 feet long) was about 88 lbs per minute. The amount of blowing snow (that associated with precipitation) increased considerably as fresh snow became available to be blown along the surface. During the storm period of 29-30 July, 1 gm am-2 min-1 was measured as moving along the surface or about 1500 lbs per minute moving past the area of the three foot fence. About two-thirds of the snow accumulated around the fences occurred during this period in which the three foot fence was covered and snow reached to the top of the snow wall, allowing snow to pass over it, thus rendering it ineffective.

g. Several measurements were made of the amount of snow accumulated in the drift area around the fences. During the storm of 29-30 July, about 145 tons of snow or about 6000 gallons of equivalent water accumulated around the six foot fence. This could be a convenient method of collecting snow for a snow melter which might be located nearby.

h. In the mid-latitudes where the slat snow fence is usually used to protect a roadway, a 20% reduction in the amount of snow blowing over the road could be an economical factor. However, on this ice cap with several thousand square miles of snow available to move past a given installation, a 20% reduction would hardly be effective. A solid barrier such as the snow wall accumulates all its snow on the windward side. Thus a snow wall or empty oil drums stacked on top of each other and spot welded together could be utilized. The wall would be effective until the windward side of the wall became filled. At that point, a new row of drums or blocks of snow could be added to give additional protection.

3. White-out and Heat Balance (23.2)

a. The purpose of this project was as follows:

(1) To study the atmosphere conditions associated with white-out phenomena.

(2) To study and measure the reduction of visibility due to both white-out and blowing snow.

(3) To measure the heat balance on the Greenland Ice Cap

b. In addition to the meteorological variables previously listed, the following radiation measurements were made.

(1) Incoming solar radiation

(2) Reflected solar radiation

(3) Sky radiation

(4) Normal incident solar radiation

(5) Incoming all-wave radiation

(6) Outgoing all-wave radiation

c. Measurements were made between 5 July and 8 August. Skies were generally cloudy during this period, the mean cloudiness being eight tenths (0.8) where one (1.0) is an overcast condition. During this period the approximate incident solar radiation was 20,000 gm cal cm^{-2} and the snow surface reflected about 85% of this radiation.

d. The net radiational balance of the snow cover which includes both long and short wave radiation was very close to zero. The effect of this zero radiation balance is reflected in the small change in cold content of the upper 100 cm of the snow which was 160 cal cm^{-2} on 8 July and 196 cal cm^{-2} on 6 August 1955. Cold content is defined as the amount of heat required to bring the snow to zero degrees centigrade. Thus the larger the cold content, the colder the snow. Since the cold content was slightly larger on 6 August, the snow cover became colder during July which is about the warmest month of the year at the location of FIST CLENCH (Site Two). This is due to the high reflecting power of the snow surface, the loss of heat transfer by either convective processes and/or heat of condensation. There is reason to believe that if there had been less clouds, the snow cover would have become even colder.

e. The amount of sky radiation was measured and found to vary from 15% of the total incoming solar radiation during the afternoon to 30% during periods of low sun angle (near midnight).

f. Measurements were made of the incoming solar radiation at three levels above the snow surface during periods of blowing snow. It was observed that the largest values of incoming radiation occurred nearest the snow surface. This is believed to be due to a reflection phenomena produced by the blowing snow near the surface.

g. The Bell solar generator, which converts solar energy to electrical energy was found to have an efficiency of 12%. It was observed that the output of the solar generator was the same whether the instrument was normal to the sun or facing the horizon. This indicates that the high reflecting power of the snow may be used to increase the conversion of solar energy to electrical energy.

h. The mean wind velocity was observed to increase with height over the snow surface and the wind profile can be expressed by an equation of the form:

$$u = K \ln Z$$

where "u" is the wind velocity at height Z. This indicates that the wind on the ice cap is not a typical glacier wind since in glacier winds, the wind velocity usually decreases with height above the snow surface.

i. Restricted visibility at FIST CLENCH (Site Two) during the period of study was caused by the following either singly or in combination: ice crystal fog, water droplet fog, falling or drifting snow. Restricted visibility was not always accompanied by the true white-out wherein diffused light lessens and sometimes removes entirely the contrast between snow and sky.

j. Observations during periods of restricted visibility were made in four ways:

(1) Determination of the visual range by use of landmarks at known distances.

(2) Detection of shapes and change in colors of targets at various distances.

(3) A crude photometric screen to enable a more objective determination of the effect of scattering, absorption and reflection by the intervening atmosphere.

(4) Sequence photography of targets during varying visibility.

k. Samples of particles of ice and/or water suspended in air were collected on a vaseline covered slide and photographed for later determination of their nature, number and size. These measurements will provide an index to the density of particles in the air. The correlation between this figure and the visibility will be a subject of subsequent study.

l. A new field instrument developed at SIPRE was tested on snow in order to determine the application of Coulomb's Emperical Law to snow. These tests indicate that the angle of internal friction for new snow varies between 30° - 35°. A coarse granular type snow which was encountered about 35 cm below the snow surface could not be compacted by loads as high as 3 psi, but had a higher angle of internal friction than finer grain snow.

m. In cooperation with personnel of Project 13, studies were made on the effect of various ground pressures on the change in density of a snow cover. This information is needed in trafficability studies. Loads varying from 0.5 to 3.0 psi were imposed on about 20% density snow in the field. The results indicate that the change in density approaches a maximum at values of 3 psi and the relation between change in density and load can be expressed by an equation of the form:

$$\Delta\rho = e^{\ln P}$$

where $\Delta\rho$ = change in density

P = ground pressure, psi

Annex N

PRELIMINARY REPORT
Project 24 Part I (Ice Cliff Studies)

PROJECT ENGINEER: Richard P. Goldthwait

1. Objective: Project 24 Part I was conceived to determine how ice cliffs on the margin of an ice cap behave, how they are maintained from year to year, and if possible, how they originate.

2. Plan: The site is at the north end of the ten mile long ice cliff on the east edge of North Ice Cap, Stensby Land. Red Rock Lake in the northern tip of Nunatarssuak was selected as a camp site on 20 August 1954 by Drs. Nobles and Goldthwait on a reconnaissance flight. Plans were laid in October 1954 and January 1955, implemented by a contract in April 1955, number DA-11-190-ENG-19 between the Corps of Engineers U. S. Army and the Ohio State University Research Foundation (Project 636).

3. Procedure: Preparations and purchase of scientific equipment were made in May 1955; personnel and equipment were transported to Red Rock Lake during the first half of June. Instrumentation was accomplished largely during the second half of June, and observations were made from 16 June to 30 August. One half of the party evacuated on 20 August and the other on 30 August.

4. Accomplishments

a. Camp was maintained by a manager, Mr. Sanderson, who prepared meals, kept ration inventory, ordered supplies, and supervised all clean-up. In addition the party leader, Dr. Goldthwait, made daily work plans, prepared reports weekly, and handled all messages. An enlisted radioman, Cpl McKenzie, maintained regular radio contact and handled messages when possible, about 40% of the time. All persons devoted concentrated short periods to settling camp early in the season and to evacuation in late August. All together these activities took 143 man-days or 21% of the total effort. Only 3 man-days were lost due to minor injuries; these were tended by an enlisted medical aidman, Cpl Storey.

b. A precise baseline 1320 feet long was established near the base camp by cementing fifteen 2 x 4 station posts three feet down into the permafrost. Precise third order measurements were made early and late in the summer of the separation and elevation of baseline stations (Mr. Jury and others). From each baseline stake pictures were taken on a 10 day schedule with a T-30 Wild Theodolite to make photogrammetric measurements of the exact position and contour of the ice cliff. Theodolite (t-2) measurements of twenty-three targets set into the cliff face gave control (Mr Jury). An accurate level survey was made from the cliff base line to five 2 x 4 posts set nine feet deep in ice, up to three-fourths of a mile up on the ice cap to determine motion after one year (Mr Jury and others). These efforts took 95 man-days or 14% of all work time.

c. A seismic survey was accomplished by a special team (Lt Pomeroy, Mr Bentley, and Pvt Dorman) in the three days 8-11 August with the aid of some of the regular party. Profiles of ice depth to the rock bottom were made in a "T" with its base at the face of the ice cliff. Backpacking the 500 lb. of gear made progress slow; a concentrated 16 man-days 2½% of work time, was so used.

d. The physical properties of the ice were studied by digging by hand pick a 100 foot long tunnel under 90 to 100 feet of ice and placing pegs in the walls every six feet. The spacing of these pegs was measured to 1/1000 of an inch eack week (Mr Hilty and others). Cores were taken by auger for approximate density measurements of ice. Six thermocouple cables were drilled 11½ to 26 feet deep into the tunnel head, the cliff face, and the ice surface above to determine the deep temperature profile in the ice; these were remeasured each week (Mr Hilty). Also the total melting back of the cliff face was measured each week on 42 stakes at various elevations. Total time: 95 man-days or 14% of effort used mostly by tunnel digging and drilling.

e. Structure features within the ice such as cracks, lineation bands, stretched bubbles, and shear planes exposed on the ice surface for one-half mile back of the ice cliff were measured and plotted on a plane table map (Dr Merrill and Pvt Dresser). Measurement was made of similar features in the tunnel and seven selected cores of ice were studied on the universal stage for crystal orientation (Dr Merrill). Some cores are being returned in refrigeration for further study and colored ice cores were inserted in the drilled holes to detect changes of shape over the next year (Pvt Dresser). Time used on this project: 57 man-days or 8½ of effort - mostly mapping.

f. Horizontal movement of stakes set five feet in ice at 42 points on the ice cliff face was measured from three baseline stations by T-2 theodolite every other week (Dr White). Four stakes on the ice above were read also. This was supplemented by a continuous recording of motion (cryokinegraph) by a wire from the ice cliff which turned a drum as the glacier advanced. Detailed micromeasurements (to 1/1000 inch) were made on five other short wires attached to pipes in shearing ice near the base of the cliff and read by microscope (Dr White). Most of the time required was to drill in stakes; this took 97 man-days or 14½% of the effort.

g. The amount of snow or ice disappearing or added between 18 June and 29 August was measured against some 75 stakes all over the drainage basin (Mr Farrand and others). Measurements were repeated every six days and supplemented by a continuous recording drum (ablatograph) which kept automatic record of the melt rate alone at one place (Mr Farrand). The area of snow cover was plotted on air photographs every fifteen days, and the area of the drainage basin was mapped by plane talbe once (Pvt Dresser). Boundaries of the drainage area were determined by dring streams. In addition the water runoff was measured by gauging the discharge at the outlet to Red Rock Lake and by continuous recording of water level in the lake (Mr Farrand). Supplementary hourly readings were made on two small inlet streams over 24 hour periods to determine differences in melt rates in different areas. The principle time consuming efforts were setting the ablation stakes five feet into ice and locating the stilling well for water-level recording and in mapping: 84 man-days, or 12½ of work time.

h. To account for the changing melting rates and provide daily weather information four weather shelters were maintained with continuous recording from 18 June to 29 August: 4 thermographs, 2 barographs, 1 actinograph, 1 hygtrograph, as well as 4 anemometers, 2 wind vanes and other non-recording instruments. Records were changed weekly or daily, and certain stations were read daily (Mr Farrand). Most effort went into establishing the weather shelters: the total was 27 man-days or 4% of work time.

i. The recent history of the ice cliff was sought by a series of studies of the ice edge and of regional deposits. All the glacial deposits were mapped for two miles out from the ice cliff and a sequence of events was worked out from the circumstantial evidence. Samples were taken for further analysis and 41 stone counts were made to determine the directions of former ice motion (Mr Gregory). Supplementary studies of the rock types carried by the ice and the size of the dirt load at 12 places on the ice cliff were made (Dr Goldthwait). The sediments in the bottoms of nearby glacial lakes were cored under the lake ice for a microscopic study of the history these layers may reveal (Dr Goldthwait). During the month of August the plant communities were studied in 6 habitat types of three typical areas to see what these might show of recent history of the ice edges and melt water -(Dr Wolfe). Total working time: 62 man-days or 9% of the effort.

5. Difficulties

a. Although all plans set forth in advance were carried out except aerial photography, certain problems reduced the total amount of work which could be accomplished, as follows:

(1) The very early beginning of the melt season by 6 June 1955 resulted in the loss of some melt runoff record before 16 June. This work must be begun before 6 June 1956.

(2) Melting on the ice cliff is so much faster than that of ordinary horizontal ice surface that stakes six feet deep will not last the melt season. Longer stakes, techniques for deeper drilling, and a light chairlift movable to any part of the ice cliff are needed.

(3) All glaciological work involves drilling and any device or laborsaving method will increase the work done. We suggest: a better variety of drills, a bailing device for dry snow and one for water, a casing to extend through wet snow and ice to eliminate refreezing water, and shorter extensions for drilling on the ice cliff.

(4) The aerial photography requested and planned was cancelled due to a combination of bad weather and the requirement that this mission be carried out on the same flight with others. This was the only total failure in the 1955 plan for Ice Cliff study (2 man-days were lost in preparation for cancelled flights, also). This might be prevented again if separate missions may be arranged for separate projects.

(5) Since it was found that dangerous ice falls take place from ice cliffs mostly during June, and decreasing in July, the safest time to implant cliff markers is early autumn. This was done in-so-far as possible for 1956.

(6) An isolated camp which is dependent upon helicopter service needs radio communication all the time for safety in the event of illness and for effective logistic support. Generator failures hampered arrangements for special helicopter flights, aerial photography, visiting personnel, and battery charging needed for two of the scientific projects (4.3 and 4.8).

(7) Many problems encountered in putting men into the field with properly sized serviceable clothing, or in supplying additional needs later, will be eliminated by a consolidated one-place one-agency source of all supplies. Scientific and personal supply, ordered and promised in advance must be held back for the party intended. Whereas supply and rations were delivered promptly in 1955 some valuable scientific time may be gained by consolidating paperwork.

6. Results

a. None of the data has been analysed and indeed some laboratory tests must still be made. These are but a very few of the interesting facts which became evident in the field work:

(1) The ice is approximately 190 feet deep within 1/8 mile back from the ice cliff.

(2) The ice at the bottom of a shaft 100 feet back of the cliff face has not disturbed the rocky ground beneath nor even lichen communities, but instead it has flowed "plastically" over it.

(3) The ice is closing in on the tunnel (deforming) at a rate of 1/10 to 1 inch per week, probably in irregular or jerky fashion.

(4) Density of the ice quarried varied from 0.82 to 0.92.

(5) Temperature of the deep ice is nearest 12°f and the freezing temperature line for summer penetrated to 4 feet below the ice surface in 1955.

(6) Melting of the ice cliff is slowest at the top (about 4 feet in 1955) and fastest at the bottom (8 feet) these being 2x to 4x as great as that on the horizontal ice surface above.

(7) Shear bands and foliation are steepest near the ice toe at the cliff base and they are very gently inclined under the ice 100 feet back from the cliff.

(8) Air bubbles are present in bands and most but not all bubbles are elongated by past deformation.

(9) The top of the ice cliff moves fastest (½ inch per day) with only half as much motion at the base of the white ice and a rapid decrease in rate of motion to 1/10 inch per day only 6 feet down in the brown ice below the white ice.

(10) The fastest motion recorded occurred regularly at night.

(11) The ice surface melted down as much as 30 inches just back of the ice cliff; lesser amounts of melting occurred during 1955 down to 0 near snowline.

(12) Most of this melting was concentrated in 1955 in about four periods of 3 to 5 days each between 16 June and 28 July inclusive.

(13) Stream flow reaches a sharp daily peak in direct response to melting at about 1430 hours near the ice edge and at 1900 to 0200 hours in the lower drainage basin.

(14) The highest air temperature recorded at the ice edge in 1955 was 47°f in late June, reflecting the early beginning of the melt season. Lowest temperature was 16°f after mid-August demonstrating the usual nightly cooling as the sun gets lower. The 1955 season was unusually cool after 15 July.

(15) Over-run lichens, plants, and patterned soil all suggest that this edge of North Ice Cap is advancing or has held its position for several decades. Stonecounts suggest that it has invaded areas covered by the main ice cap centuries ago.

7. Recommendations

a. In order that plans may be laid for 1956 these preliminary recommendations are made.

(1) The data taken in 1955 must be worked up and analysed. This will require additional funds under the present contract.

(2) A quick trip requiring two scientists and logistic support in March 1956 to Red Rock Lake ice cliff would add very valuable data to that already gained. Instruments already established would tell the effect of winter on ice temperature, glacier motion, tunnel closure and snow accumulation.

(3) The camp at Red Rock Lake should be reestablished about 1 June 1956 for a smaller party of about eight men (5 civilian scientists, and 3 enlisted men supporting). Although some scientists might come and leave for shorter periods the observations should continue to 30 August 1956 for comparison with 1955. At that time the camp might be removed for good.

(4) Gravity measurements should be made in detail based upon the seismic control now at hand to provide a detailed contour map of the rock floor under this ice basin.

(5) Aerial photography, omitted in 1955, must be carried through in 1956 if complete surface map control is to be had.

(6) Physical measurements of the ice should be expanded to include detailed strain gauge measurements of ice deformation over short periods in the tunnel, and bubble studies of confining pressures.

(7) The man-days for structural studies, especially ice petrofabrics, were too limited in 1955 for satisfactory conclusions. It is proposed to continue and intensify this effort in 1956.

(8) The baselines are already established and need only be remeasured for frost heaving and motion in 1956. Photogrammetry can be reduced to one series of pictures and readings in August 1956 for comparison to the 1955 surveys. It is believed that a simpler and more easily obtainable instrument may be used.

(9) Motion measurement studies need not be enlarged but they should be continued on the limited number of stakes (30)

now reestablished. More instrumentation in the form of several motion recorders (cryokinegraphs) will add greatly to information obtained in 1956 with a minimum of effort.

(10) Measurements of melting (ablation) can be continued readily on stakes now established and automatic recording of drainage will take a minimum effort now that instruments are set up.

(11) Climatic studies should be redirected by reducing the number of recording stations scattered around, moving the upper station to firnline, and establishing microclinatological apparatus at the ice cliff face to determine temperature, humidity, wind and radiation gradients by readings at close intervals.

(12) Historical studies (geomorphology) should be greatly reduced since they are essentially complete, except that some concentrated effort to unravel the history of nearby glacial lakes by mapping shorelines and coring sediments may supplement previous information by adding figures for actual years.

(13) So much information was revealed by the small exposure of the rocky floor beneath the glacier in a shaft 100 feet back from the cliff edge that extensive tunnelling in 1956 along the bottom and along one or two shear planes is recommended. This should be followed by a day to day study by a geomorphologist.

(14) A number of experienced persons from the 1955 project will be available for the 1956 operation or for March 1956 readings.

PRELIMINARY REPORT
Project 24 Part II (Steep Ramp Studies)

PROJECT ENGINEER: Laurence H. Nobles

1. Introduction: This portion of the operation was carried out from the camp at Red Rock Lake. The party consisted of three men during the month of July and two men during August. The purpose was to obtain detailed information on the steep ice ramp or, more properly sloping ice cliff formed by the North Ice Cap at the point where it is in contact with the main ice cap.

2. Accomplishments

a. Eighty-two specially designed, semi-permanent stakes were set along four profiles across the sloping cliff of North Cap and along one profile on the main ice cap. The relative positions of the tops of these stakes was determined by as precise surveying as was possible under the conditions. Distances were determined in part by taping, in part by use of a precise invar subtense level. In most cases a closure of 0.01 feet or less was obtained between adjacent stakes. On the steeper slopes it was necessary to resort to vertical angles for determination of elevations.

b. A stadia and transit traverse was run from Red Rock Lake along the base of the sloping ice cliff to tie the profiles together. This traverse was closed to bedrock at the northeast end.

c. A major portion of the time in the month of August was spent in preparation of a plane table map of the ice structures in the area adjoining the ice cap junction. This included mapping of both shear features and tension cracks and is an attempt to study the relation of ice structure to cliff formation.

GLOSSARY

Ablation..........Net loss of snow or ice by melting, sublimation, evaporation, or wind action during a specific period of time. It is usually expressed as the water equivalent of the snow or ice lost. The opposite of accumulation.

Accumulation......Net gain of snow or ice during a specific period of time. It is usually expressed as the water equivalent of the snow or ice gained. The opposite of ablation.

Algal Pits.........Pits formed in ice by thawing due to absorption of solar heat by masses of microscopic algae and inorganic sediments.

Blink.............The reflection on the sky (clouds, overcast) appear-over open water on cold days. Sometimes known as landsky or watersky.

Blue Ice..........Clear ice without snow cover.

Crack.............A narrow cleavage in sea, lake. or icecap ice. On glacier and icecaps, generally considered a crack if approximately 12 inches or less in width.

Crevasse..........A wide (wider than a crack) cleavage in the snow or ice of a glacier or icecap. Many reach extreme widths and depths, of the order of 50-75 feet wide and 190-200 feet deep and occasionally greater.

Cryoconites Holes..Holes formed in the ice by thawing due to absorption of solar heat by organic sediments.

Drainage Basin.....Zone of icecap preceding head of a glacier. Zone where movement of glacier is already noticeable by presence of crevasses.

Dry Snow Zone......Zone of icecap where maximum temperatures are not high enough to permit melting.

Fault.............Any fractured surface along which there has been a relative displacement of rock in any direction parallel to the fractured surface.

Fjord............Long inlet of the sea between steep, high banks formed by glacier.

Firn Line.........The line on the icecap above which firn exists and below which the snowfall of the current year completely melts away. Line of demarcation between zones of ablation and accumulation.

Glacier...........Ice moving slowly down a mountain or valley. Generally crevassed.

Hummock...........A round or dome-shaped irregularity of the ice surface usually a few feet high and common to the heavy melt conditions of the ice ramps.

Ice-Blink.........Reflection of an ice surface on clouds.

Ice Cap...........Dome shaped snow or névé covering large areas of land Example: Ice Caps of Greenland, Ellesmere Island, Antarctic.

Ice-Field.........Large coherent mass of pack-ice, several miles in area. Small icecap.

Ice-Floe..........Same as ice-field, but smaller and generally flat.

Ice-Pack or Pack...Sea-Ice of considerable extent, compact; composed by fields, floes, ice-bergs and polar ice. Froze in a solid mass during the winter. In constant movement during summer under the action of currents and winds.

Ice Ramp..........An inclined ice surface from the land onto the icecap over which surface travel is possible.

Lead..............Long crack in sea or lake-ice, with open water.

Marginal Zone......A vaguely delineated fringe area of the icecap in which the topography is extremely susceptible to climatic influence, i.e., melting, movement, drainage, etc., as contrasted to the higher and interior portions of the icecap, which are not subject to climate changes. The conditions of the marginal zone (crevasse, melt streams, hummocks etc.) nfluence the movement of vehicles.

Melt Stream.......A stream of water produced by melting snow and ice in the marginal zone which cuts its own stream bed as it flows down the ice ramp.

Moraine............An accumulation of dirt, gravel, and small and big boulders which has reached its present position through being transported by a moving glacier.

Nèvè..............Persistent and generally hardened snow. The icecap of Greenland is mostly nèvè (not ice) covered with snow.

Nunnatak...........Land (mountain tip or dome) emerging from icecap (as island emerges from sea.)

Permafrost.........Ground, wet or dry, in which the temperature is always below freezing.

Polar Ice..........Fields or floes from the Arctic Sea. Generally thicker than ordinary fields or floes .

Ramp...............An inclined surface of ice and snow used as an access to the cap.

Run-off............Melt water flowing off a glacier.

Saracs.............Ice cliffs, ice pinnacles on glacier surface.

Sastruggi..........Ridges or waves of snow created by wind. Generally occur in high parallel series. Can be several feet high and several hundred feet long.

Snow Bridge........The snow mass that sometimes covers the surface opening of a crevasse.

Thaw Zone..........Edge of the icecap where melting of snow in spring and summer occurs. Generally limited at altitude line of 4500 feet. May extend several miles inland onto the icecap.

Wannigan...........The American and Canadian Army term for the crew quarters on a swing. A house built on a sled.

PICTORIAL DATA

Project Number	Sequence Letter	
1	A.	10 Yard truck unloading subgrade at end of approach road.
2	A.	Personnel of the 1st EATF using hand gas engine driven auger to place post holes for transfer point.
3	A.	T-4 snow compactor used at Site #2 on the snow compacted runway.
3	B.	Method used to refuel pulvimixers at Site #2.
3	C.	Section of completed Snow Compacted runway.
3	D,	C-124 making touchdown on completed snow compacted runway.
3	E.	Tracks of aircraft at turnaround area of Snow Compacted runway
3	F.	Rutting in area where snow had drifted over completed runway, resulting from test landing of aircraft.
13	A.	Peter Sr. Snow Plow.
13	B.	Peter Jr. Snow Plow under operation.
13	C.	Trench covered with chicken wire covered with polyethelene film.
13	D.	Trench covered with plywood supported by 2" X 4" and in foward section, hardware cloth covered with polyethelene film.
13	E.	Pitched roof covering wide trench.
13	F.	Cantilever beam of snow used as experimental trench roofing.
13	G,	Surface view of covering of chicken wire and polyethelene film being anchored into position.
13	H.	Personnel taking snow samples from side of trench.
18.1	A.	Polygon area under study.
18.1	B.	Excavation to assist in study of disturbed features.
18.2	A.	Individual polygon isolated for study.
18.2	B.	Precision measurement of polygon.
18.2	C.	Thumocouple installation in polygon field.
22	A.	End of Ice Tunnel with measurement pegs secured on face.
22	B.	Rock outcrop which obstructed tunnelexcavation.
23	A.	Snow fence built from blocks of snow.
23	B.	Meteorlogical station at Site #2.
24.1	A.	Algal pits.
Tuto	A.	Fuel barrels used as forms for foundations of Modular building built by the 1st EATF for the use of Transportation Corps.
Tuto	B.	Modular Shop buiding under construction.
Tuto	C.	20 Foot by 48 foot Quonset Hut under construction.
Tuto	D	Packaged Latrine unit installed in a 20 foot by 48 foot TO&E type building.
Tuto	E	
Tuto	F.	
Tuto	G.	Warehouse-Mess Hall built by 1st EATF Personnel in Engineer Camp Area.