Special Report 73

USA CRREL ICE CHIPPER

by

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PREFACE

This report was prepared by Mr. Guenther E. Frankenstein, Applied Research Branch, Engineering Division. The author wishes to thank Dr. Andrew Assur, Scientific Advisor, and Mr. William Parrott, Chief, Measurement Systems Research Branch, for their many helpful suggestions. Dr. Assur conceived the original idea of the ice chipper and also of the mining teeth. Without his ideas and push the ice chipper never would have materialized. Mr. Parrott was responsible for some of the original ideas and his ideas and suggestions for modifications to the original machine were invaluable. The author also wants to thank Mr. Wm. Wagner of Calumet and Hecla Inc. for his excellent job in designing the ice chipper. He also wishes to thank Mr. Francis Gagnon for his many suggestions and Mr. Lawrence Anderson, who as operator contributed much to the success of the chipper.

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CONTENTS

ILLUSTRATIONS

TABLES

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INTRODUCTION

Runway construction on the arctic pack is made difficult and sometimes impossible by the prescence of hummocks and pressure ridges. The normal method of site selection is to pick out an area that is far enough away from a pressure ridge and appears to be free of hummocks. In almost all cases, though, hummocks will be present once the snow is removed. These hummocks must be removed before the runway can be put into operation.

A hummock is formed when a pressure ridge heals itself through years of weathering; its surface becomes very smooth. By this time most of its brine will have drained out so it will be harder than the surrounding ice.

The hummock problem first came to the attention of CRREL when Dr. Assur was at McMurdo, Antarctica, and again when Dr. Assur and the author were on Drifting Station Alpha. They noticed that it was taking longer to remove one hummock than to construct an entire runway. They decided at that time to attempt to design a machine that would be capable of removing these hummocks.

The ice chipper, as it was named, was to be an attachment that would be part of a complete runway construction kit. The chipper would have its own power for ice chipping but would depend on a prime mover for mobility. The prime mover would be a construction-type front-end loader equipped with forks that would be used for lifting the attachments. The kit would also include a bucket and blade for snow removal. A crane hook for lifting items such as oil drums, and a rotary snow blower would also be provided. This snow blower would supply its own power for blowing snow and ice chips, but would depend on the prime mover for mobility.

To make this kit completely operational and independent it was decided that each piece would be capable of being air-dropped. This required that each piece meet Air Force requirements regarding size and weight for air-dropping. This requirement put a severe limit on gross weight of the prime mover which in turn also put a weight restriction on the ice chipper.

DESIGN

Tractor

The major requirements for the prime mover were that it be a track-laying front-end-loader tractor, meet weight requirements for air dropping, and have a minimum forward speed of 0.2 mph. A survey of the available tractors showed that the Caterpillar Model 933 Traxcavator met all of the requirements except for speed. The Caterpillar Company suggested that by eliminating the standard counter weight and winch a hydraulic drive could be installed. This hydraulic motor, supplied by oil under pressure from the main engine, would drive the tractor through the rear of the main transmission to give a continuously variable speed forward from about 0 mph to the maximum speed of the tractor. This met with approval, and such a tractor was purchased to be delivered to the Keweenaw Field Station, Houghton, Michigan, for testing. It was found necessary to attach a bracket to the lower rear of the tractor that would hold approximately 1500 lb as a counterweight. This increased the tipping load of the tractor enough to allow the ice chipper to have a maximum of 6800 lb.

Ice chipper

A literature survey was made to find any available information that would help in the design of a chipper. A letter was also sent to a number of manufacturing companies in an attempt to arouse interest in the project. Through this it was discovered that the Navy Civil Engineering Laboratory, Port Hueneme, California was conducting a feasibility study on a design of an ice grader. The requirement for the ice grader was that it be able to level an ice runway as a road grader could level a roadway. The teeth of the ice grader would be shaped in the form of an ice pick or spike. (CRREL was considering mining teeth that would chip the ice.) A copy of the report from the NCEL study was presented to CRREL which, combined with the discussions with the NCEL personnel, was a valuable asset in the design of the CRREL ice chipper.

Requirements of the chipper drum

It was decided to have the drum rotate upwards at the front to gain maximum operation, control, and to reduce the force necessary to remove the ice. It was also decided that the teeth would be standard chipping teeth or bits that are common to mining machines. The teeth would be so mounted that replacement would be no problem. Since the drum would rotate upwards at the front, the teeth would have to be set so that they would help to move the chips outward. Earlier SIPRE* experiments showed that the teeth should be placed so that the tooth following the cutting tooth should be from $\frac{1}{2}$" to $\frac{3}{4}$" offset on the horizontal. Using this information it was decided to have four rows of teeth in a helical pattern with $\frac{5}{8}$" between cutting tooth and following tooth. This gave approximately 180 teeth if placed on a 24" drum. From this then it was calculated that a minimum of 100 hp would be needed to cut and move the chips.

A list of the requirements was made up and included in an invitation to bid for the design and construction of the machine. The only requirement other than the drum itself was that the rpm of the drum could be varied so that the optimum cutting speed could be found. A number of manufacturers sent proposals, with the Calumet Division, Calumet and Hecla, Inc., of Calumet, Michigan, being the low bidder.

Mr. William Wagner of Calumet and Hecla was responsible for the final design of the machine. He placed the teeth so that there were 176 of them on the drum (Fig. 1).

TESTS AND MODIFICATIONS

The original machine (Fig. 1) was first tested at the Keweenaw Field Station on ice that had been removed from the lake and piled up on the shore. During the first tests the number of teeth and rpm were varied in an attempt to find the right combination. The results showed that the most efficient chipping occurred when only half of the teeth were used and when the drum rotated at 425 rpm. The only real problem was that the chips did not move to the side sufficiently. It was then decided to replace the drum with an auger so that the chips would be carried to the right or discharge side.

Specifications for an auger were sent out to a number of manufacturers for bids with the E. D. Etnyre Co., of Oregon, Illinois submitting the low bid. They constructed the auger and welded the bit holders to the auger flight. There were now 2 rows of teeth with the following tooth offset $1\frac{1}{2}$" on the horizontal from the cutting tooth.

The new auger was first tested at the Keweenaw Field Station and then on the rough ice near the shore of Lake Superior. The tests were very successful. The chipping action was excellent and the movement of the chips to the discharge side was vastly improved. It seemed that the chips were building up near the discharge point; the hood was modified to open up on the right end to help remedy the situation. An improvement was noticed but there was still some build up of the chips. The machine was considered ready for operational use and was sent to Barrow, Alaska, for actual field tests. A new auger that had seven changes in pitch and bit holders mounted on the inside of the auger and two new type deflector hoods were constructed and sent to Barrow, Alaska, for testing (Fig. 2-4). These items were constructed to improve the chip discharge rate.

At Barrow, Alaska the chipper was tested under actual conditions (Fig. 5, 6). The roughest area of sea ice was found and two 500 x 30 foot strips were laid out. Salinity profiles are shown in Figure 7. There was a 14 foot high pressure ridge within the first 100 ft of each strip. Both augers were tested for production. The

*Now a part of USA CRREL.

auger with the single pitch, 24 inch, removed the pressure ridge and rough ice at the rate of 37 tons per hour and on a straight run averaged 94 tons/hr (Table I). The auger with the changes in pitch averaged approximately the same tonnage on the rough ice but averaged 116 tons/hr on the straight run. This auger also moved the chips to the side much better than the single-pitch auger. The rotary snow blower was used to remove the snow and ice chips that remained on the roadway. The new or chipped ice surface was ideal as a road or runway surface (Fig. 8).

FUTURE PROGRAM

The ice chipper will perform its first operational task during "Deepfreeze 65". It will work along with the NCEL ice chipper at McMurdo, Antarctica, where there is a requirement to construct a road through a heavy pressure ridge area. The chippers will also remove any hummocks that may appear on the crosswind runway whose construction is scheduled to begin early in 1965. In addition to such tasks, the ice chipper could be used for constructing access roads over glaciers and ice caps.

Table I. Production capacity of ice chipper (over flat smooth ice surface).

Location	Date	Type of ice	Average depth of cut (in.)	Length of cut (ft)	Production (tons/hr)	Temperature (-C) air	ice	Remarks
Houghton, Mich.	8 Mar 1962	Lake ice	1.2	200	69.3	1.9	1.0	24" pitch
Barrow, Alaska	21 Feb 1963	Sea ice	1.6	50	89.4	33.0	23.2	24" pitch
Barrow, Alaska	21 Feb 1963	Sea ice	1.6	50	97.7	33.0	23.2	24" pitch
Barrow, Alaska	2 Mar 1963	Sea ice	2.2	500	126.1	26.0	23.0	Changes in pitch
Barrow, Alaska	4 Mar 1963	Sea ice	2.4	500	106.6	32.9	23.5	Changes in pitch

Average depth of cut is the average of the depths measured every 5 feet on each side of the 8-ft 2-in. cut, over the total length. The ice temperature was measured approximately 2 in. below the ice surface.

Capacity over rough sea ice and pressure ridge area -37 tons/hr.

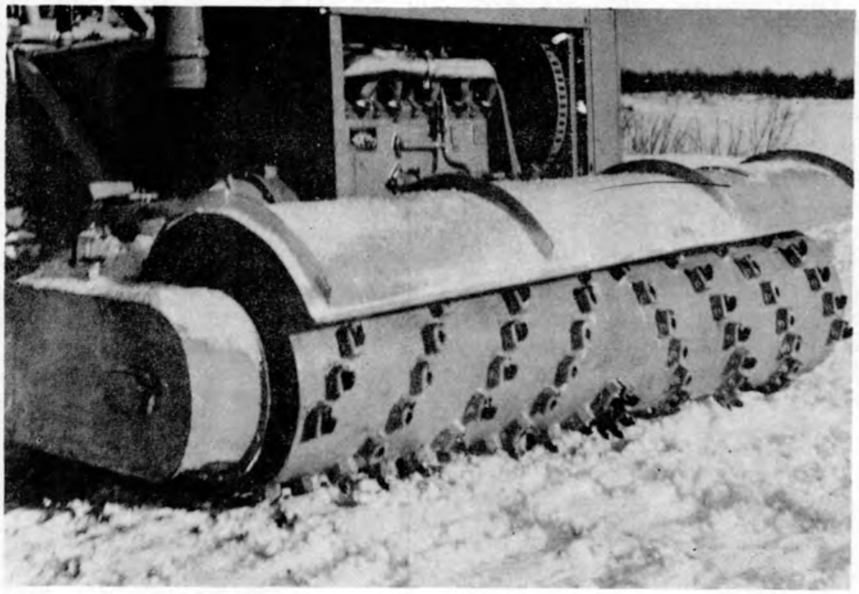

Figure 1. Original ice chipper.

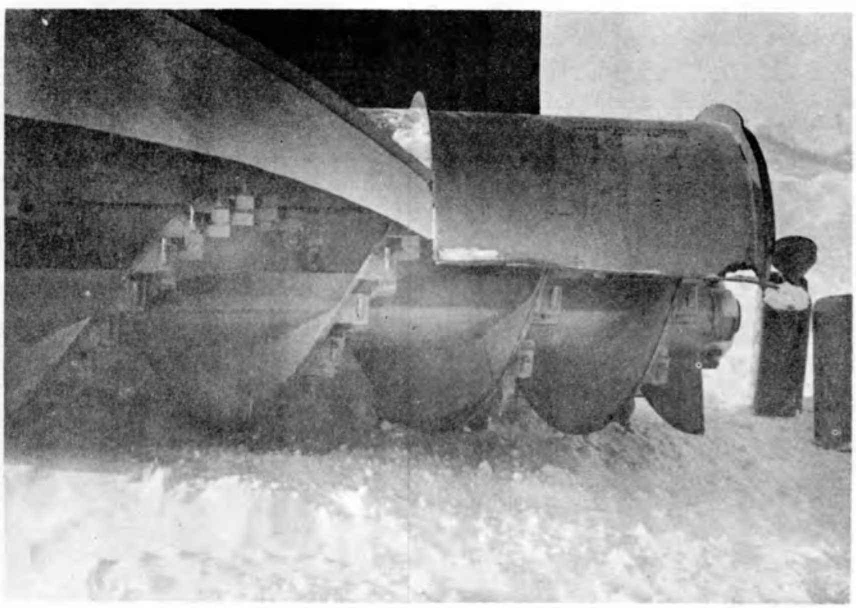

Figure 2. Change-in-pitch auger with opened-up hood.

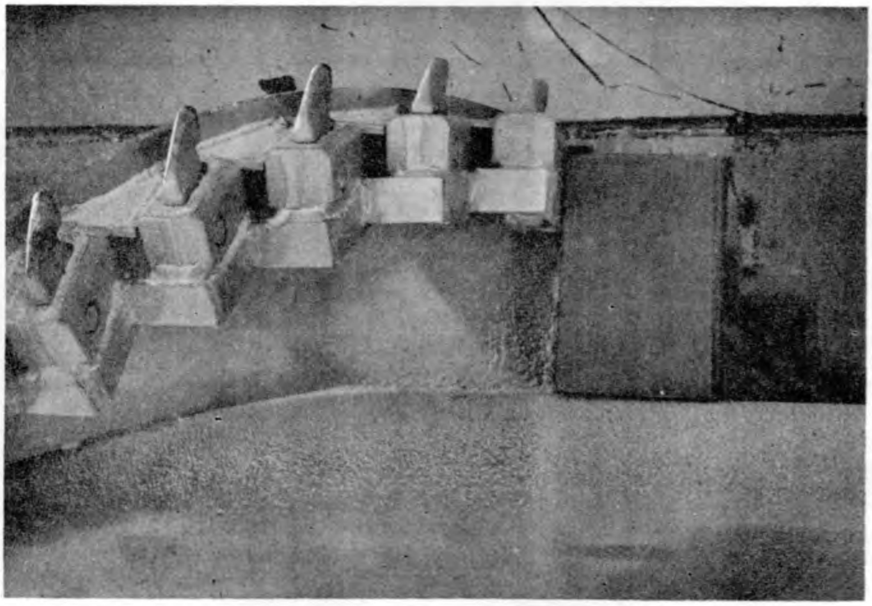

Figure 3. Closeup of teeth and their mounts. The bit holders are welded to stripping which in turn is welded to the auger flighting.

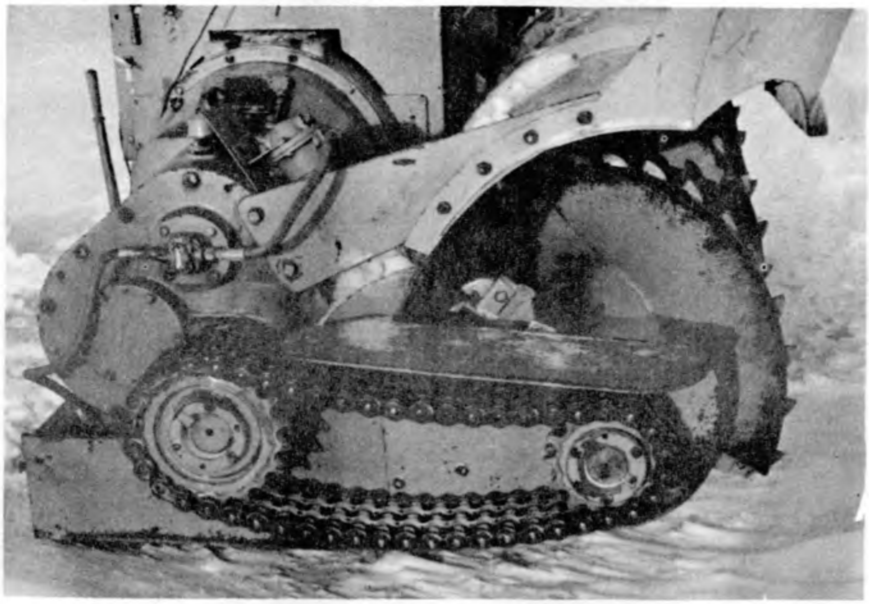

Figure 4. Side view of unit. Note the new chain guard which allows more room for chip discharge.

Figure 5. Ice chipper working on top of pressure ridge. Notice that ice chipper is in a raised position.

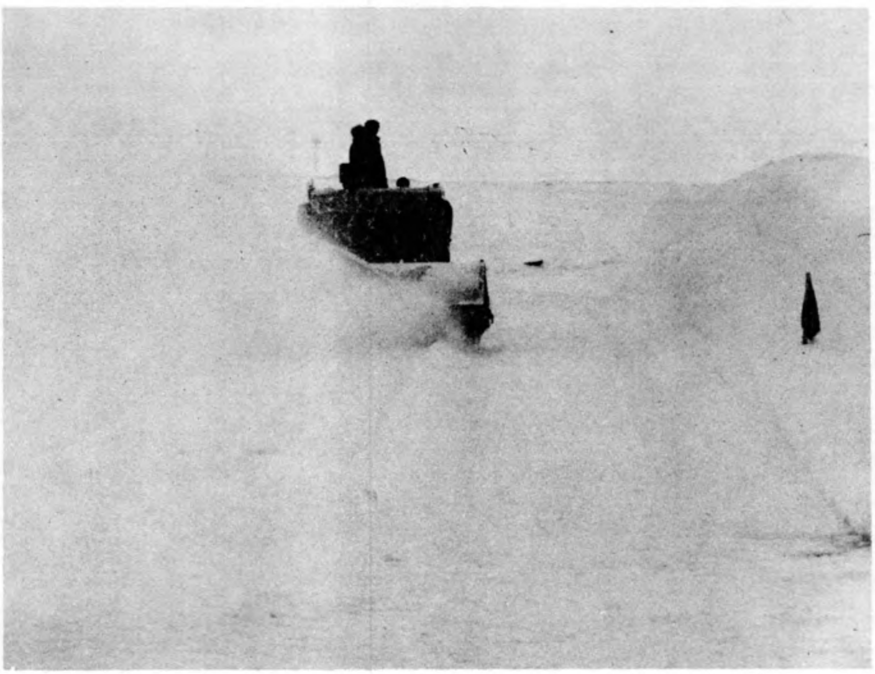

Figure 6. Cut-away view of pressure ridge that was shown in Figure 5. Note that the chips are being moved to the discharge end.

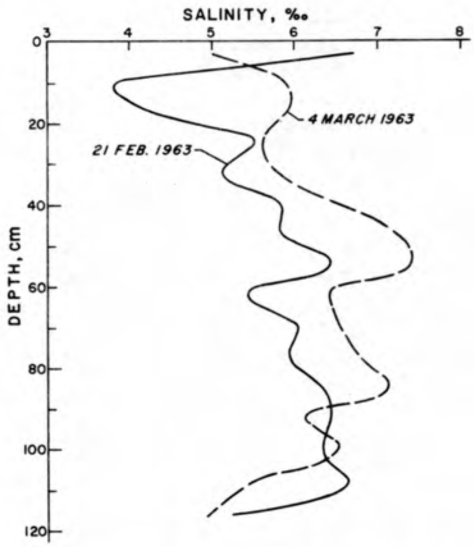

Figure 7. Salinity profiles were taken near the test site, Barrow, Alaska. These profiles are normal salinity profiles for sea ice of the area.

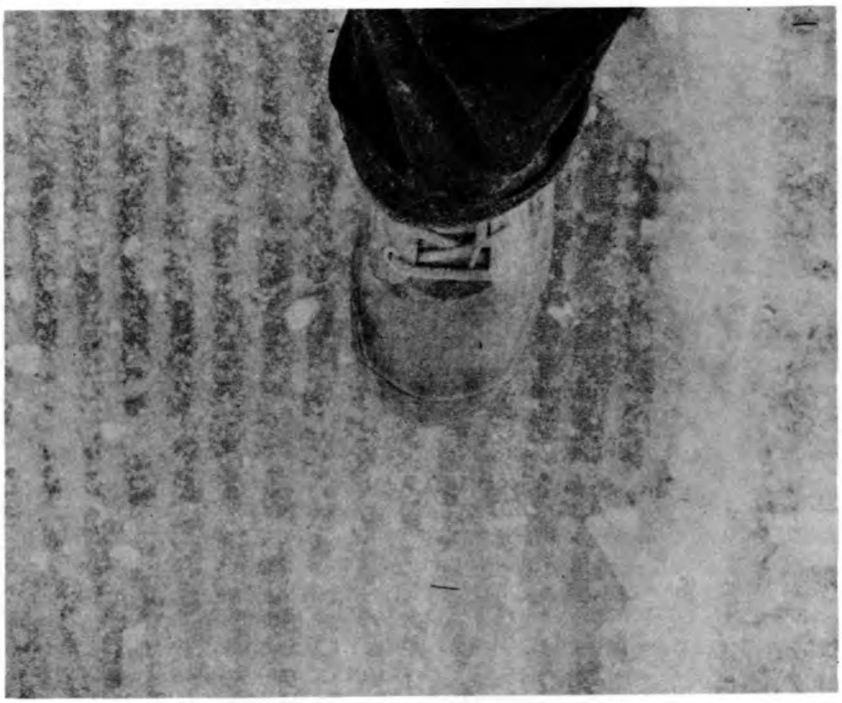

Figure 8. Ice surface after cutting by ice chipper. This makes an ideal road or runway surface.

APPENDIX A: PRODUCTION CAPACITY

To state the exact amount of ice that the ice chipper can remove over rough pressure-ridged ice is impossible. The production capacity for a given pressure-ridge area can be easily determined by taking a level survey before and after cutting but this capacity would be for that area only. Height, width, and age determine the time required to smooth a ridged area and could vary from 10 to over 50 tons/hr. The ice chipper's ability to be moved in the vertical direction gives it a tremendous advantage in removing pressure ridges.

The production capacity of the ice chipper over a smooth surface and straight run depends a lot on the ability of the operator. The more familiar the operator becomes with the machine the greater the production. This is true with most equipment of this type. Our tests show that production increased with each test. (The maximum run was 199 tons/hr in March 1964.) In one test the operator was instructed to take a maximum cut at the fastest speed at which he could maintain control. The horizontal length of the tests varied from 50 to 500 ft and the average depth of cut was computed by averaging the depth measured on each side of the cut or from the measurement taken in the center of the cut. The time required for each test was also recorded. From this information the production capacity for each test was easily computed.

Table A1. Production data, 50-ft length of cut with 24-inch pitch auger. Barrow, Alaska, 21 Feb 1963.

Station (ft)	Run 1 Depth of cut (in.)	Run 2 Depth of cut (in.)
0	0.5	1.2
5	1.8	3.0
10	0.2	0
15	0	0
20	2.8	2.5
25	2.8	3.2
30	1.0	0.5
35	1.5	0
40	2.0	3.5
45	2.5	3.5
50	0.5	0

Depth of cut was measured in the center

Time required: Run 1, 61 sec.
Run 2, 58 sec.

Table AII. Production data, 500-ft length of cut with change-in-pitch auger, Barrow, Alaska, 2 March 1963.

Station (ft)	R. side Depth of cut (in.)	L. side Depth of cut (in.)	Station (ft)	R. side Depth of cut (in.)	L. side Depth of cut (in.)
		2 March 1963			
0	2.5	2.5	260	0.0	3.5
10	5.3	5.5	270	1.0	3.8
20	2.2	4.5	280	1.4	5.0
30	0.0	0.0	290	4.5	2.5
40	4.3	0.5	300	1.0	2.5
50	2.4	2.8	310	3.3	2.5
60	1.6	1.5	320	1.2	0.5
70	0.0	0.0	330	3.0	4.0
80	4.9	1.2	340	1.6	2.5
90	8.6	6.2	350	3.0	3.3
100	5.3	4.0	360	2.6	3.0
110	0.8	2.0	370	1.8	0.0
120	0.6	2.7	380	2.2	3.0
130	0.0	3.2	390	3.2	2.5
140	1.4	0.5	400	1.4	3.5
150	0.0	0.5	410	1.2	1.0
160	0.8	3.8	420	5.3	4.0
170	0.0	0.0	430	3.2	0.5
180	0.8	4.2	440	4.1	2.3
190	4.3	0.5	450	3.0	0.0
200	0.8	2.8	460	5.9	2.5
210	1.2	0.5	470	0.0	0.0
220	0.0	2.0	480	0.0	3.0
230	1.0	0.0	490	0.0	0.0
240	3.3	6.2	500	1.8	0.7
250	0.8	0.0			

Time required, 10.2 minutes

		4 March 1963			
0	2.8	3.9	260	0.0	0.0
10	1.6	1.0	270	3.7	1.6
20	0.4	1.2	280	0.4	1.0
30	1.4	2.6	290	2.6	0.8
40	2.4	0.0	300	2.6	1.0
50	1.6	0.0	310	0.0	1.2
60	1.6	0.6	320	1.0	1.4
70	8.4	6.5	330	3.0	1.4
80	4.9	7.2	340	1.4	0.0
90	5.5	7.9	350	1.2	0.6
100	5.5	8.1	360	3.9	0.8
110	1.2	3.7	370	1.4	0.2
120	3.7	4.7	380	3.7	3.5
130	0	6.5	390	0.6	0.2
140	2.6	2.8	400	2.2	0.6
150	4.1	5.5	410	1.2	0.0
160	0.6	5.3	420	3.3	0.8
170	0.2	3.7	430	5.3	2.7
180	2.8	8.1	440	4.3	0.6
190	0.0	3.9	450	0.6	0.0
200	1.6	4.7	460	4.1	3.9
210	3.0	5.7	470	3.2	0.4
220	0.6	5.1	480	1.0	0.2
230	0.8	1.4	490	3.9	4.1
240	4.1	4.3	500	0.2	0.2
250	0.4	0.2			

Time required:		
	0 to 100 ft.	3.5 min.
	100 to 200 ft.	2.8 min.
	200 to 300 ft.	2.3 min.
	300 to 400 ft.	2.5 min.
	400 to 500 ft.	2.2 min.
	Total time	13.4 min.

APPENDIX B: SPECIFICATIONS OF ICE CHIPPER*

Ice chipper

The ice chipper shall be an independent self-contained unit consisting of a gasoline-engine drive arrangement, including disconnect clutch and reduction gear box, ice cutting auger, and a suitable sub-base and auger supports. The unit shall be suitable for mounting on the lift fork attachment that is mounted on a Model 955 Caterpillar Traxcavator. Manipulation of the ice chipper while operating shall be by means of the normal loader controls of the Traxcavator. The complete unit shall not weigh more than 6500 lbs and the center of gravity of the unit when mounted shall not be more than 36" forward of the standard bucket hinge pin. The unit should be capable of making a minimum 8-inch cut before penetration is limited by any part of the auger drive or supports.

Auger

The auger assembly will have a diameter of $29\frac{3}{8}$" at the tooth tip. It will have seven (7) changes in pitch and have a $\frac{3}{8}$" x 9" double flight ribbon. The changes in pitch will be as follows: first 12" -24; second 12" -30; third 12" -36; fourth 12" -42; fifth 12" -48; sixth 12' -54; and last 26" -60. Flighting welded with 4" long weld on 12" centers to 8" OD x $\frac{1}{2}$" wall tubing 8' -2" long exact. Ends fitted with $\frac{1}{2}$" end plates with hubs 5" diam x 1" wall x 3" long. Drive and key seated and tail end plain.

One (1) 3" diameter cold-rolled shaft approximately 9' $5\frac{1}{2}$" long with ends machined to where 8" tubing meets shaft to 2-15/16", w/key seat for drive sprockets and key seat for drum bearings as well as one key on drive end.

A number of Cincinnati Mine Machine Company C-953 Rap-Lok lugs w/C-1094 bit retainers plus M-6 bits will be welded to the inside of the auger flights per location as shown on inclosed detail drawing. The whole auger assembly shall be dynamically balanced.

Drive assembly

The unit shall have Waukesha model 140GZ gasoline engine or a later model of this same engine. The reduction gear box and clutch assembly should be a Cotta model SR 972 transmission or a later model of same. The drive between transmission shaft and auger shaft shall be by sprocket and chain and as shown by detail drawing. The rpm of auger shall be between 400 and 450. A gasoline tank with a minimum capacity of 10 gallons shall be firmly attached to the steel plate that is located in front of the engine.

Paint

Finish paint shall be two coats of gloss enamel in accordance with specification MIL-E-489, color: Swamp Holly Orange - Dupont #93-1021. All workmanship and welding should meet the best of commercial practices.

*Drawings are on file at USA CRREL.

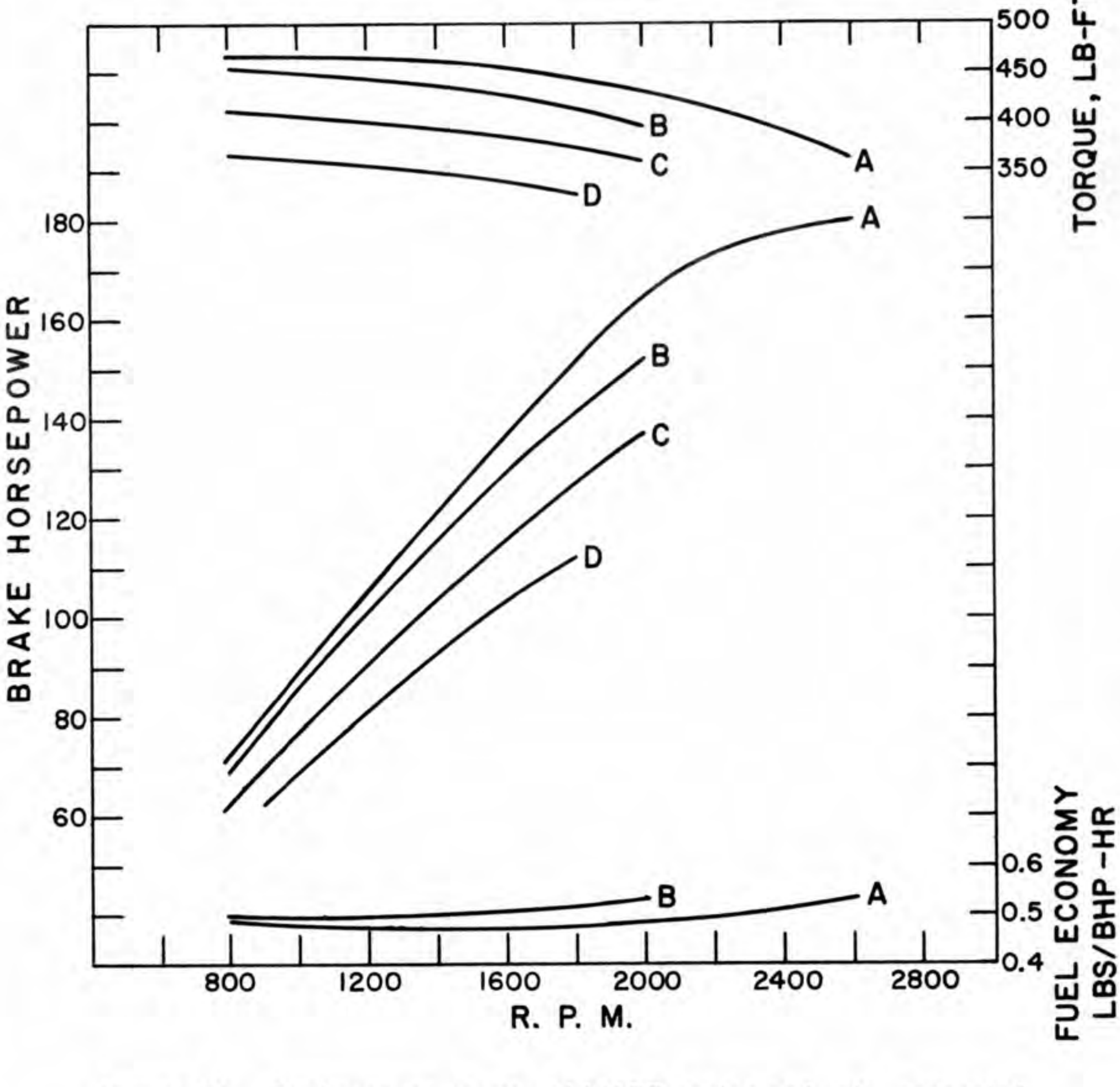

Figure B1. Performance curves of 140GZ engine and unit, corrected to 29.92" Hg, 60F. Gasoline: 85 octane (min.). Compression ratio 7.3:1. Carburetor - $1\frac{3}{4}$" updraft.

Curve A - Maximum rating of bare engine
Curve B - Maximum rating of unit
Curve C - Intermittent rating of unit—90% of curve B
Curve D - Continuous rating of unit—80% of curve B

Curves B, C and D { Oil bath air cleaner; 24" 6 blade fan at 1.2 x eng. speed; Generator }