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Limnological Survey Techniques from Small Aircraft

E.W. Marles

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INLAND WATERS DIRECTORATE
PACIFIC AND YUKON REGION
NATIONAL WATER RESEARCH INSTITUTE
VANCOUVER, BRITISH COLUMBIA, 1985

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Abstract

Methods and equipment for obtaining limnological observations from small aircraft are described. This system has enabled conductivity/temperature/depth (CTD) profiles and water samples to be collected in all seasons from a remote chain of deep northern lakes.

Résumé

Ce rapport décrit les méthodes et les matériaux employés pour obtenir des données limnologiques en utilisant un petit avion. Cela a permis de faire des relevés techniques sur la conductivité, la température, la profondeur (CTP) et de prélever, à n'importe quel temps de l'année, des échantillons d'eau d'une chaîne de lacs profonds et éloignés dans le nord du pays.

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INTRODUCTION

In the summer of 1981, the National Water Research Institute (NWRI), Pacific and Yukon Region, began a phased physical, chemical, biological and geological study of the Yukon River headwater lakes. The lakes sampled included Atlin, Tagish, Marsh, Laberge, Teslin and Bennett, thus creating a sampling region of approximately 140 by 240 km (Fig. 1). For the physics and chemistry sampling it was desirable to have, as nearly as possible, an instantaneous longitudinal section of study parameters to illustrate physical and chemical processes. We estimated that sampling the 25 stations by boat or skidoo in the appropriate season would require at least six working days, assuming good weather. Significant expenditures for establishing fuel caches would also be incurred.

Small aircraft were chosen, therefore, on the basis of speed and efficiency. The transect of stations was consistently accomplished in three days. The speed of the aircraft sampling permitted the exploitation of smaller "windows" of good weather.

An added benefit of aircraft sampling was the opportunity to return to the field laboratory in Whitehorse to process physics data, which ensured data quality, and to prepare chemical samples. When projected costs, including manhours, logistics and fuel, of boat sampling were compared with costs of aircraft sampling they were found to be roughly equivalent.

This paper will describe the specific equipment developed for both summer and winter sampling in a remote northern environment, using a variety of small aircraft. An inventory of equipment can be found in Appendix C.

CHOICE OF AIRCRAFT

A sampling routine was developed, with the objective of using the smallest (most economical) aircraft suitable to the task. Our requirements included the ability to use a winch to deploy an Applied Microsystems CTD to 300 m, the ability to sample water to 300 m, and the ability to carry two technicians to do the work. We were also limited to the available charter aircraft in the region. For summer operations in the Whitehorse region this choice included Cessna 185F, Cessna TU206G, De Havilland DHC-2 "Beaver," and DHC-3 "Otter" aircraft, all on floats. The Cessna 185F on floats was too small and had inadequate door access; the De Havilland aircraft were too expensive to charter.

Once we had settled on the Cessna TU206G on floats for our work, a hand winch package was designed to bolt directly onto an aircraft seat track (Fig. 4) and deploy through the double rear cargo door (Fig. 2). A sample bottle rack was also designed to bolt in place in the aircraft (Fig. 3).

Similarly, for winter operations we chose the most appropriate aircraft available. The required equipment for winter sampling could be accommodated in the Cessna 185F on ski/wheels, since the equipment could be spread out on the ice for the actual sampling procedure (Fig. 6). A collapsible base for the winch was designed for ice use (Fig. 5).

When uncertainty about ice thickness made ski-plane landings hazardous, a helicopter was employed. This enabled the field party to measure ice thickness before cutting engine power. For this work we used both Hughes 500D and Bell 206B helicopters, with "Bearpaws" on the skids. Dimensions, capacity and costs of the various aircraft are presented in Appendix A.

SUMMER OPERATIONS

The summer (ice-free) sampling routine described here is the complete Chemistry/Physics program undertaken in the second phase of the duty. The initial year of survey limnology included only the physics sampling.

After landing on station with the Cessna 206, both cargo doors were opened, the winch "A" frame was extended, and the CTD instrument was deployed (Fig. 2). The second operator assisted by guiding the CTD between the floats, attaching Niskin sampling bottles to the wire, and by making Secchi depth and surface temperature observations. The CTD was lowered at approximately 20 m/min. Profiles and sampling were accomplished at stations as deep as 305 m. At chemistry stations six depths were normally sampled, requiring two casts of three bottles each. A 50-m vertical zooplankton haul was taken with a 0.5-m net. Under adverse wind and wave conditions, generally with wind speeds over 10 knots, it was necessary for the pilot to "power" into the wind to reduce wire angle owing to drift. The Cessna 206 on floats was able to land and sample in winds of 10 to 15 knots. At times it was necessary to land in the lee of a point and taxi to station.

The Applied Microsystems CTD-12 records internally on 3-in. reels of 0.25-in magnetic tape. The station data were recorded without opening the CTD case and without interim inspection of data. At the end of a day's sampling the physics data were read and processed with an Applied Microsystems MOD 769 Tape Translator and a Hewlett-Packard 85 computer.

This produced temperature and conductivity vs. depth, and temperature vs. conductivity plots, and tabulated standard depth data, which enabled the field technician to check data quality and provided an instant preliminary data report. Chemistry samples were filtered or preserved, as required, in the field laboratory.

WINTER OPERATIONS

There are both advantages and disadvantages to winter water sampling operations. The most significant advantage is that the stable operating surface of ice enables the sampling crew to spread out their gear and operate unconfined. Winter weather conditions tend to be stable for longer periods of time. Wind does not interfere with sampling except for the wind chill danger to personnel.

The disadvantages include uncertainty about ice quality while landing. Ice quality often varies with local conditions and may change significantly over short distances. Icing of sampling apparatus tends to be a problem below -10°C. Methanol was used liberally to keep ice off the equipment. It is also difficult to protect water samples from freezing at air temperatures colder than -10°C. "Overflow" of water on top of ice causes several problems. (We have found it deep enough to go over a standard 10-in. boot top!) Pilots of rotary and fixed wing aircraft are reluctant to land in overflow conditions because of the dangers of breaking through the snow to water beneath and the attendant risk of upset or difficulty on taking off again. It was usually possible to move a few hundred metres away from an obvious overflow site and find a sound landing location. This compromise of station location must be made or the station not taken at all.

The summer hand-winch assembly was modified for ice operations by providing a stand with simple push-in legs to facilitate stowing in the aircraft (Appendix B). A Stihl power ice auger was used for boring sampling holes, and a custom-designed ice chisel was fabricated for enlarging chemistry sampling holes. Usually three holes were opened out to a triangular shape for this purpose. The CTD was provided with a cage reduced in diameter for greater clearance in an 8-in auger hole. Later versions of the AML CTD-12 are reduced to a maximum 6.5-in. (16.5 cm) diameter.

INSTRUMENTATION AND DATA REDUCTION

Equipment Specifications

The equipment specifications follow:

— Applied Microsystems CTD-12 with special order dual conductivity range (0 - 0.5 ppt and 0 - 50 ppt) internally recording on 3-in. reels of 0.25-in. magnetic tape

Conductivity	0 - 0.5-ppt range locally calibrated 0 - 150 μS ±1 μS
Temperature	-2 - 30°C ±0.02°C
Depth	0 - 650 m ±0.1% Full Scale
Weight	7 kg in air, 5 kg in water

— Applied Microsystems Tape Translator Model 769, RS-232C interface

— Hewlett-Packard 85 portable computer, 32K RAM, RS-232C interface, Input/Output ROM

The CTD data are stored on tape as serial station records with no specific identification. Software was developed by NWRI Branch to process data from the Applied Microsystems CTD-12 instrument. The cycle of the instrument being lowered and raised is indicated as the depth data are displayed on the computer screen, and subsequent casts are separated by zero conductivity values. The station logbook is used to identify individual casts by their serial location on the tape. A secondary check on station location is the comparison of the field log record of meter wheel readout to the depth sensor's indicated depth. The data record for a complete station is read into the computer and stored temporarily on the processing tape. It is then converted into engineering units.

The data were edited by the field technician, usually the same day as collected. A surface value was assigned to the depth data, since there was no adjustment in this instrument to account for variation in ambient air pressure. When editing was completed, plots of temperature vs. conductivity were produced and printed by the computer's thermal printer.

When the plots were completed, the station header for the storage tape was filled in with information from the station logbook, and the data were stored on a separate storage cassette. The printed plots and summarized station data provided an instantaneous preliminary data report (Fig. 10).

SAFETY

In summer, the equipment generally carried by charter operators in their aircract was considered adequate. Field parties carried Mustang Sportswear Ltd. "Uvic Thermofloat" jackets to increase the likelihood that a life-jacket would be "on" when required, and to enhance cold water survival potential.

For winter flying operations a more conservative approach to survival equipment was followed. Field parties carried their own survival packs consisting of "arctic quality" down sleeping bags, freeze-dried foods, a small stove and a tent. "Bata" insulated boots were issued to field people, since winter sampling was to continue with temperatures as low as -40°C.

The most serious concern for safety arose from lack of prior knowledge of ice thickness. Because of concerns about the safety of ski-plane landings on Atlin and Tagish lakes, the study group started to employ helicopters. Some consideration was given to prior local reconnaissance of ice conditions but such reconnaissance was never implemented. The variability of ice conditions over small distances and the difficulty of communicating with isolated inhabitants made reconnaissance impractical.

SUMMARY

An airborne limnology sampling system has been described, which has

(a) repeatedly sampled a 400-km section in three days;

(b) sampled conductivity and temperature continuously to 300-m depth;

(c) obtained standard chemistry samples to 300-m depth;

(d) completed this program, year round, in a remote northern lake region.

ACKNOWLEDGMENTS

The work described in this report could not have been completed without the assistance of many people. E.C. Carmack initiated the development of limnological sampling methods from minimum size aircraft and encouraged the production of this report. Warren Foster fabricated much of our specialized mechanical equipment. Monty Alford provided the ice chisel specifications. Ray Kirkland assisted with field work. Ron Wiegand and Jeanne Cheng developed the data processing programs. The willing help of pilots from the various charter companies is gratefully acknowledged.

Figures 1 to 10

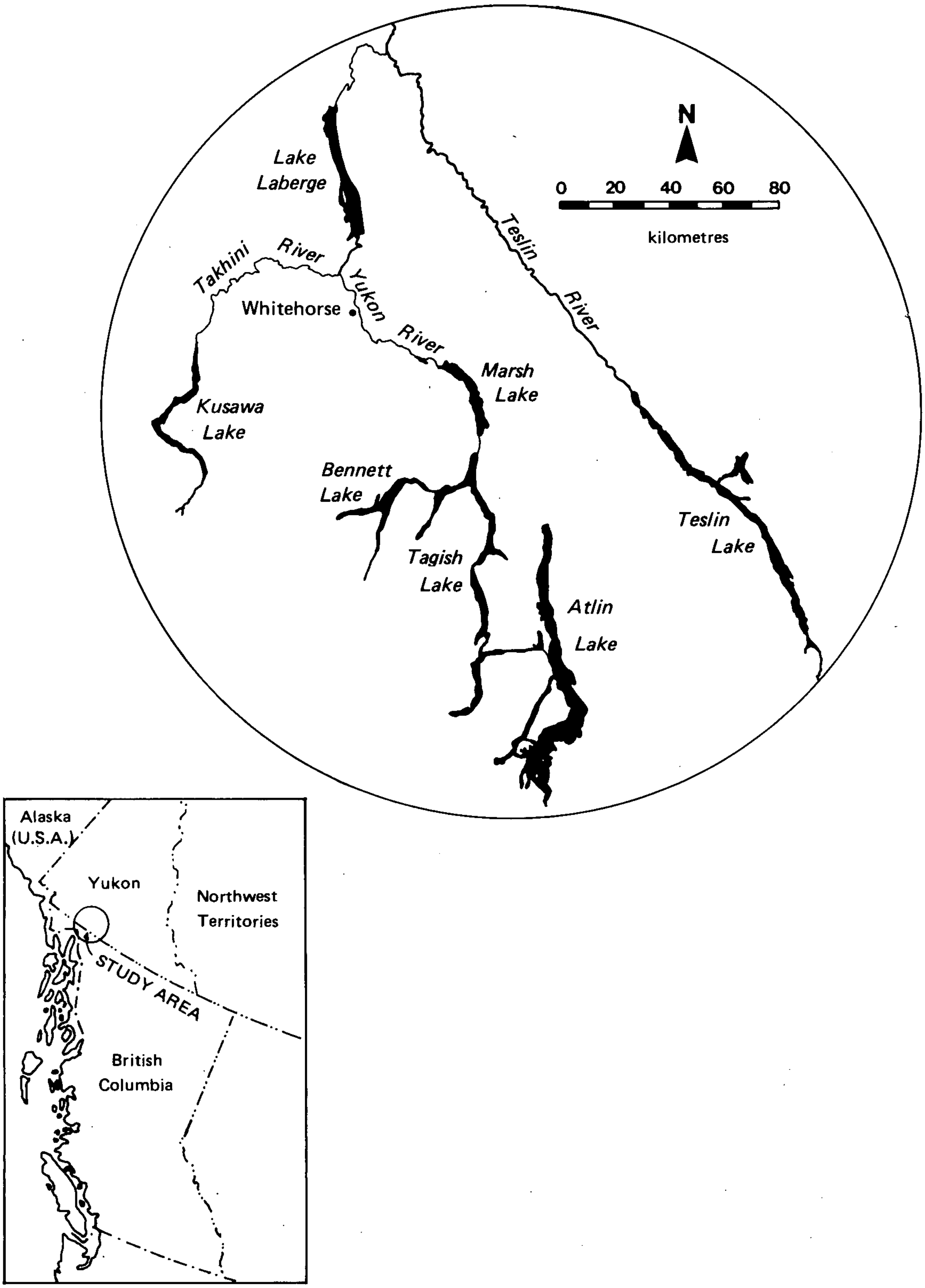


Figure 1. Study area.

Figure 2. Cessna TU206G on floats – hand winch deployed.

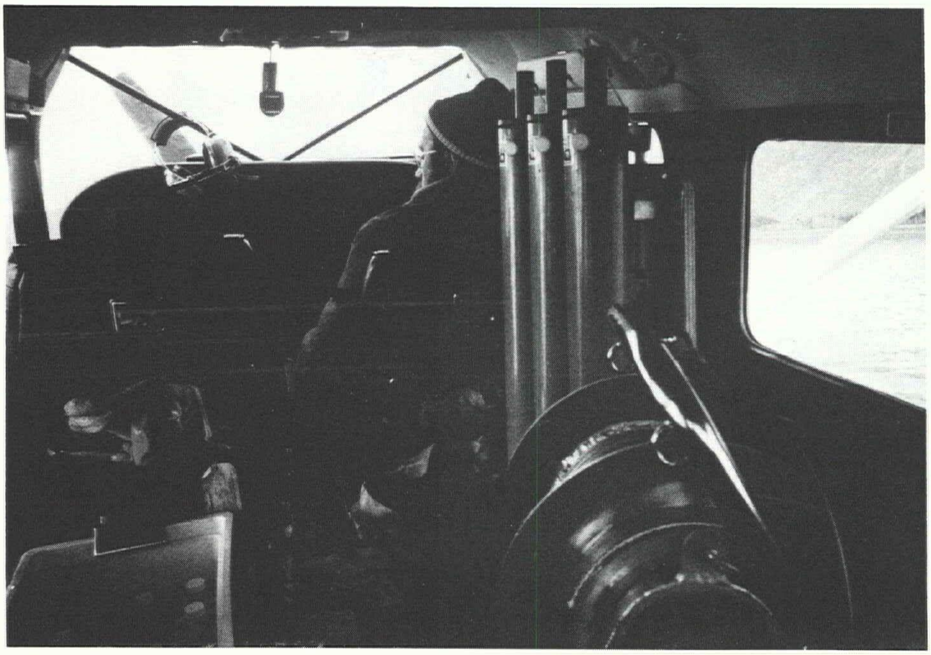


Figure 3. Cessna TU206G – interior view.

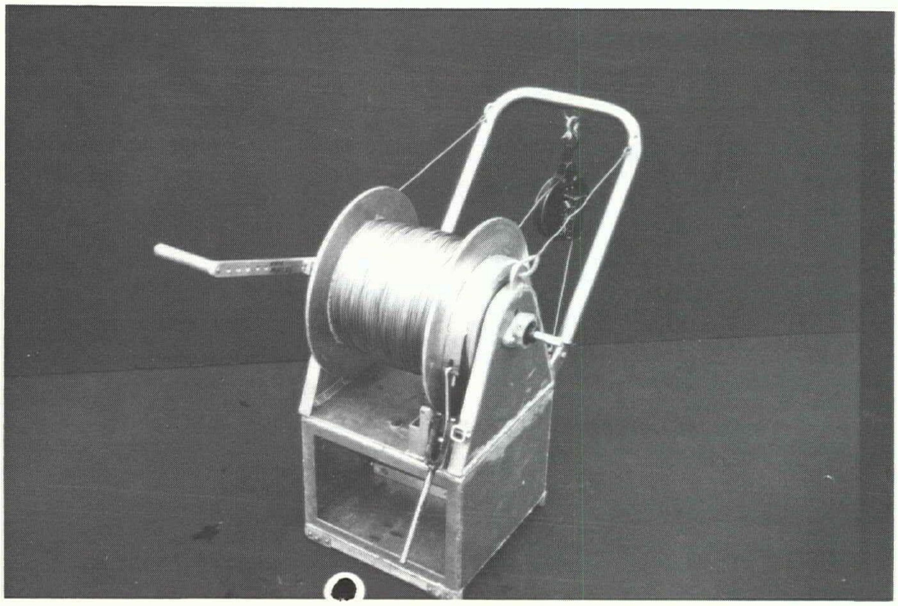


Figure 4. Airplane hand winch on seat-track base.

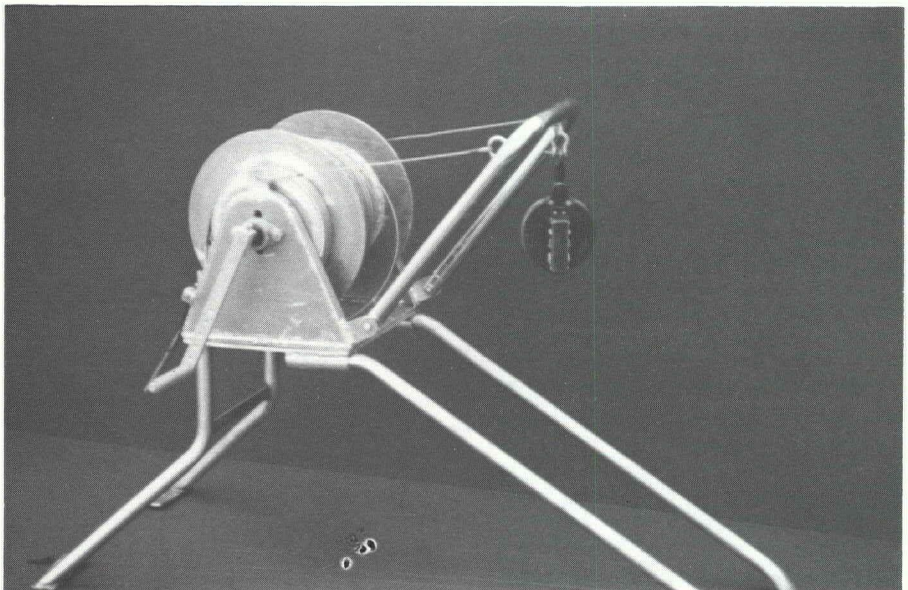


Figure 5. Airplane hand winch on ice base.

Figure 6. Cessna A185F on ski/wheels with field party.

Figure 7. Hughes 500D helicopter with field party.

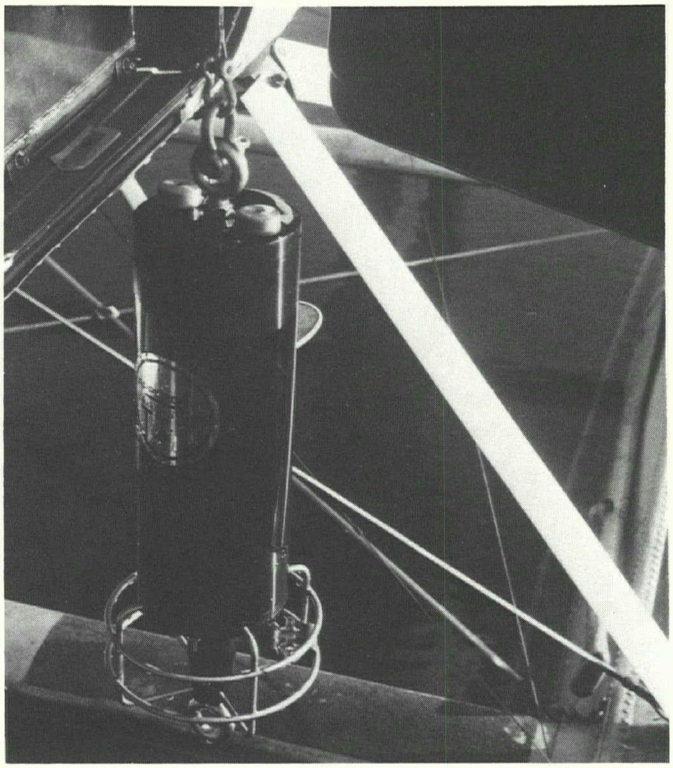


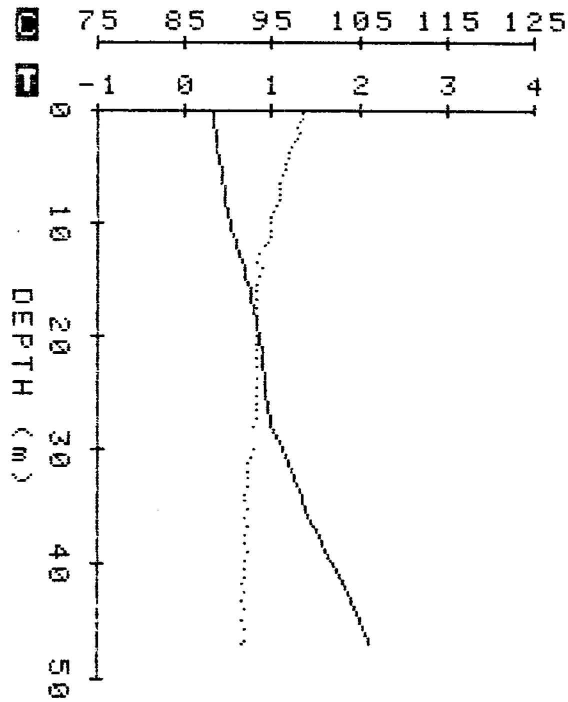
Figure 8. Applied Microsystems CTD-12.

Figure 9. Data processing equipment.

DATA STORED IN FILE LL3G
NUMBER OF RECORDS = 87
NUMBER OF SCANS = 74

AML TAPE LABEL: LLHS840327
OPERATOR'S NAME: EM
CRUISE No.: 1
DATE(yymmdd): 840327 TIME: 1046
LAKE: LABERGE
STATION: LL-3 CAST: 1
LAT: LONG:

DEPTH	TEMP	C25	TRANS
0.0	.31	98	75.9
2.0	.35	98	75.9
5.0	.41	96	75.9
10.0	.52	95	75.9
15.0	.71	93	75.9
20.0	.85	93	75.9
25.0	.92	93	75.9
30.0	1.12	93	75.9
40.0	1.69	92	75.9
46.9	2.10	92	75.9



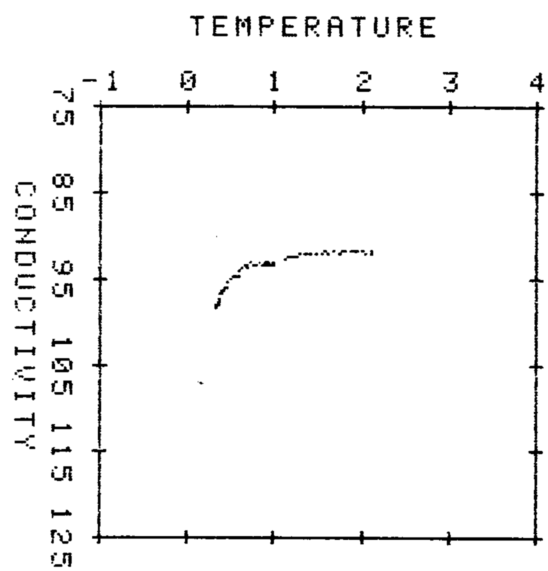


Figure 10. Sample data output.

Appendix A
Aircraft Dimensions, Capacity and Costs

Aircraft Dimensions, Capacity and Costs

Tables A-1 and A-2 provide a summary of aircraft capacity and relative costs of charter. Table A-3 contains the actual costs for flying time. The figures following the tables give the aircraft dimensions.

Table A- 1. Summary of Aircraft Capacity

Aircraft type	Weight of bare aircraft: Wheels	Skis/Skids	Floats	Gross weight	Fuel weight	Fuel consumption/h
C185	1871	2011	2163	3350	446	108
C206	2075	–	2379	3600	552	115
DHC-2	3315	–	3415	5090	640	175
DHC-3	4631	4926	5116	8000	1281	220
H500	–	1360	–	3000	412	138
B206	–	1750	–	3200	491	172

Note: 1. All weights are in pounds.
2. Abbreviations:

C185 – Cessna A185F
C206 – Cessna TU206G
DHC-2 – De Havilland "Beaver"
DHC-3 – De Havilland "Otter"
H500 – Hughes 500D helicopter
B206 – Bell 206B helicopter

Table A - 2. Relative Costs of Charter

Aircraft	Type	$ Can./min	$ Can./h	Relative cost
C185	Skis	1.25	160.00 + fuel	1.00
C206	Floats	1.50	180.00 + fuel	1.13
DHC-2	Floats	2.06	227.00 + fuel	1.52
DHC-3	Floats	2.50	250.00 + fuel	1.72
H500	Skids	–	450.00 + fuel	2.58
B206	Skids	–	500.00 + fuel	2.86

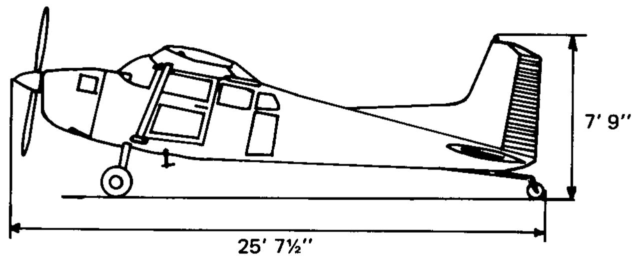
Note: 1. Based on various 1983/1984 tariffs; actual rates will vary with carrier.
2. Relative cost does not take account of greater load capacity or speed.

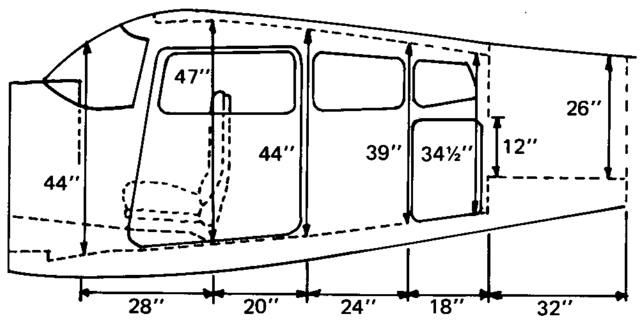
Table A- 3. Actual Costs for Flying Time

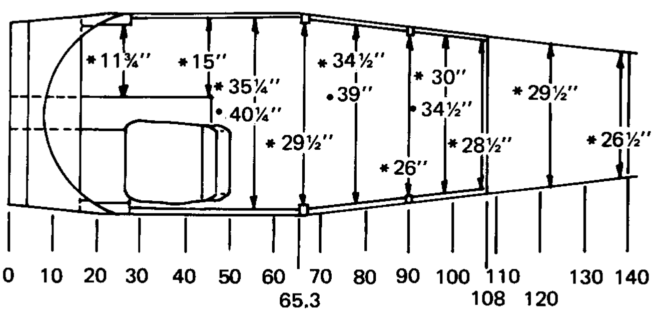
Season	Costs per survey	Costs per station
Summer 1983	$2000 Can.	$ 80 Can.
Winter 1983/84	3400 Can.	136 Can.

Note: Each survey covered a section of approximately 400 km with ±25 stations.

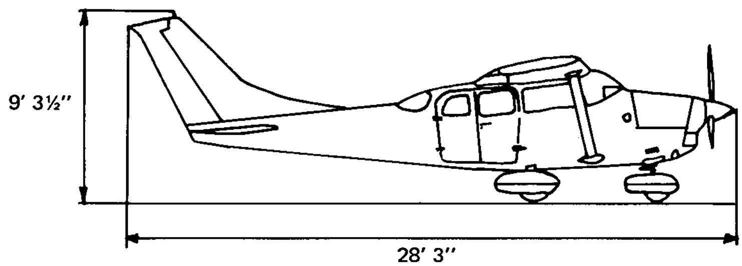
CESSNA A185F

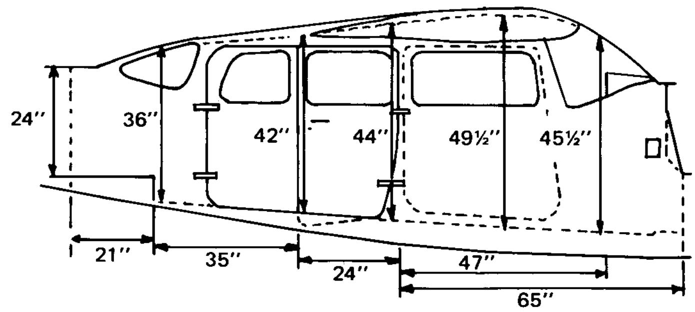


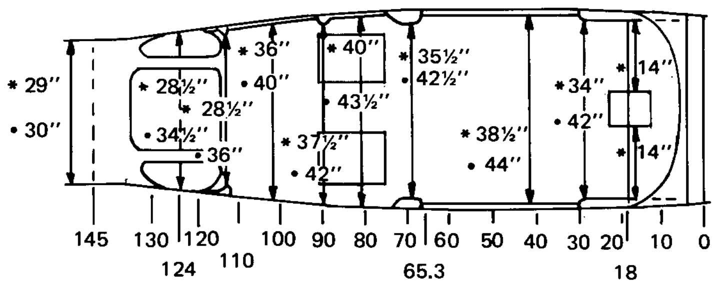




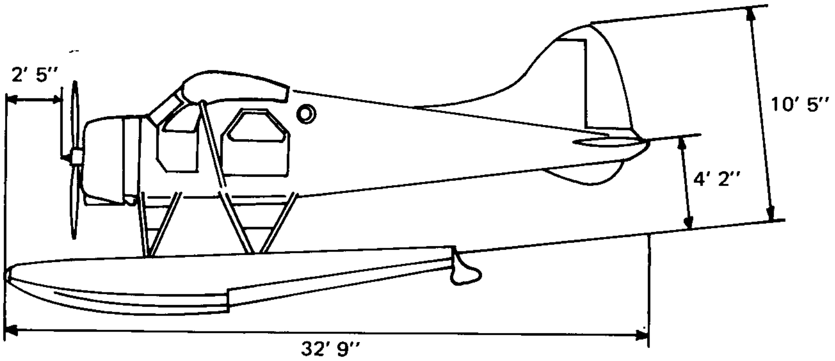
CESSNA TU206G

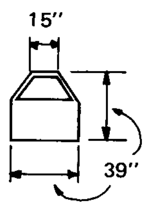




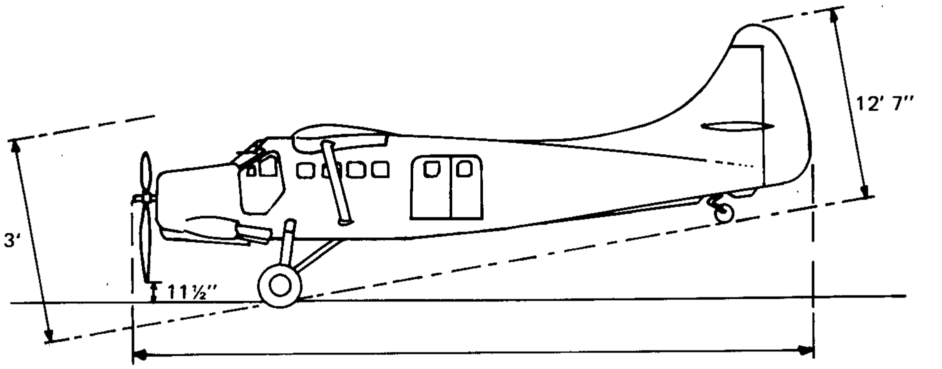


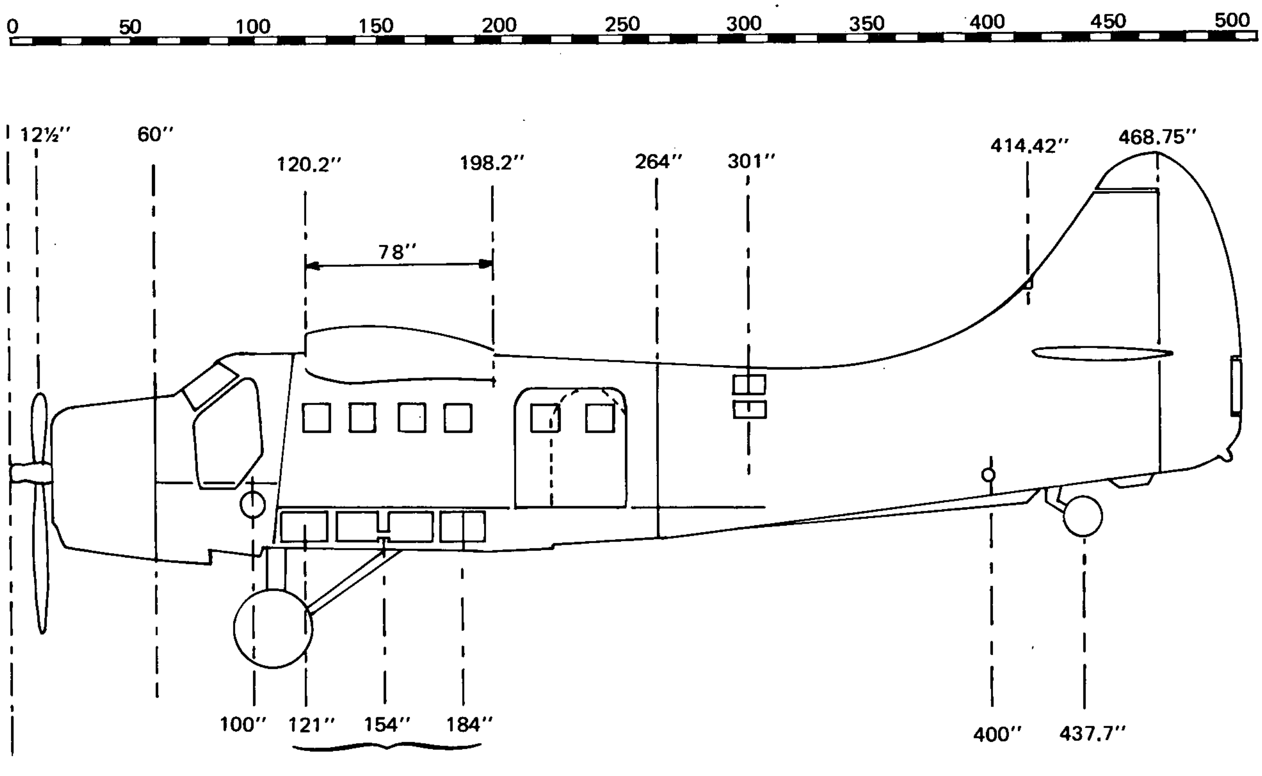
DEHAVILLAND DHC-2 "BEAVER"



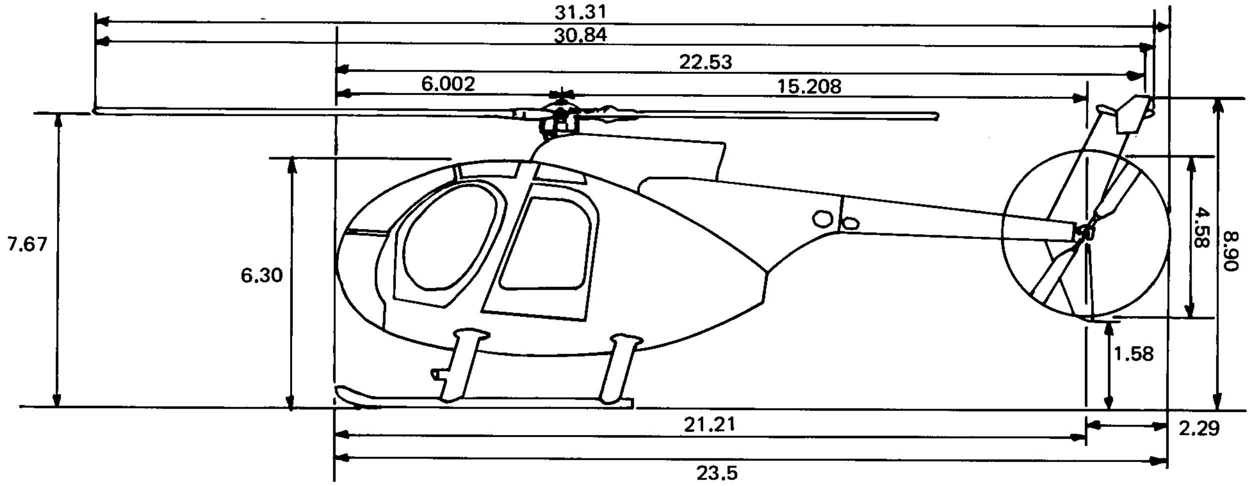


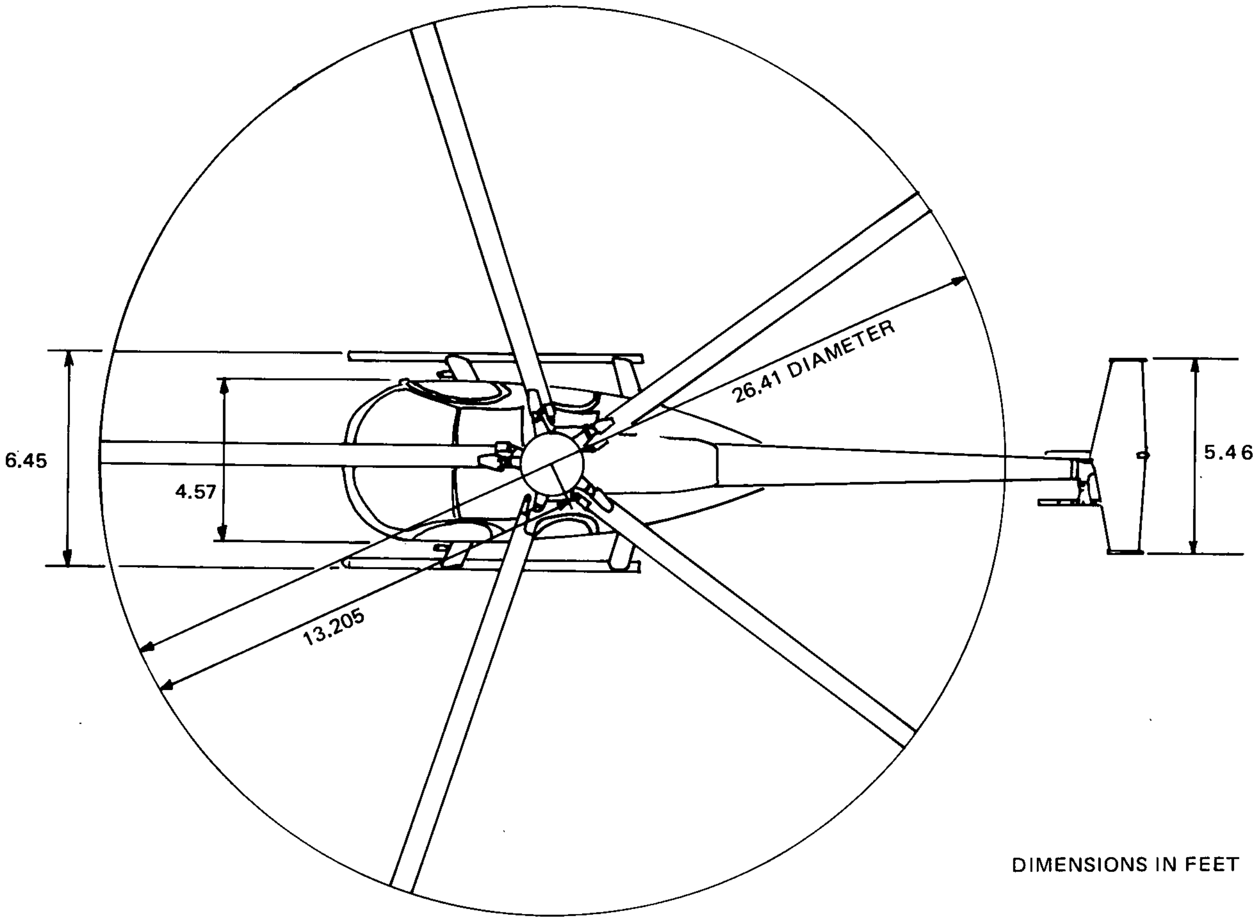
DEHAVILLAND DHC-3 "OTTER"



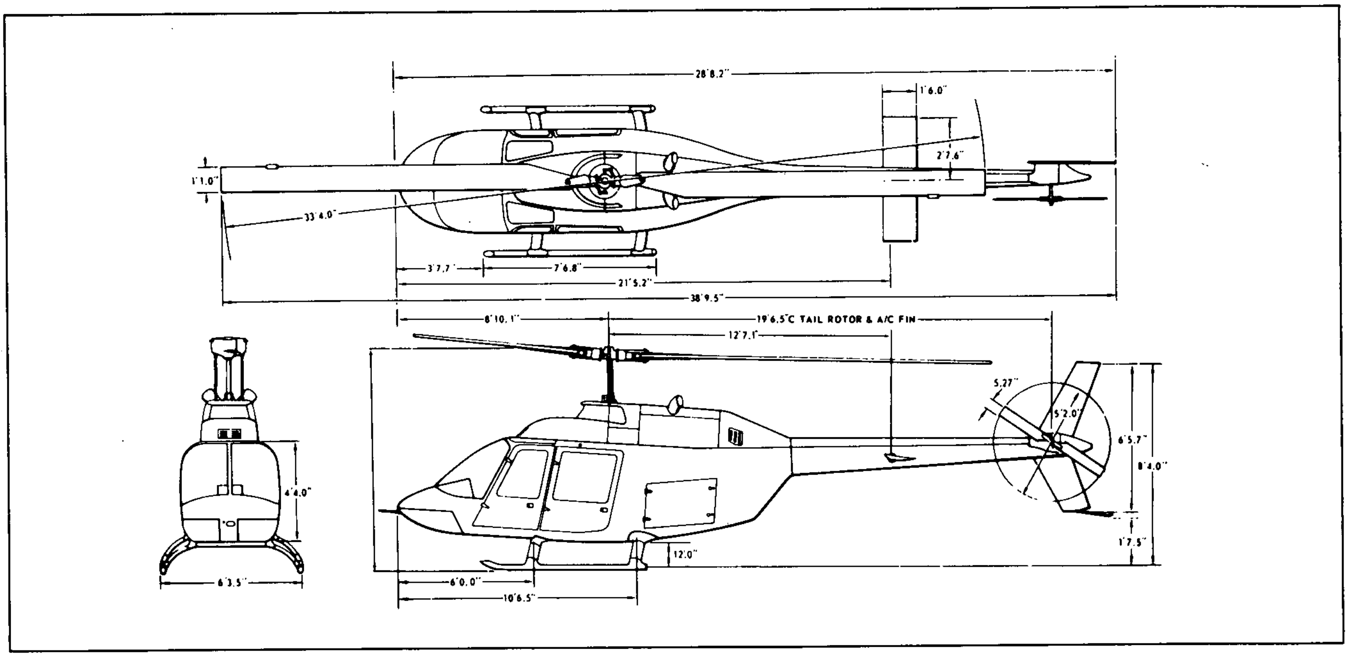


HUGHES 500





DIMENSIONS IN FEET



BELL 206B

Average cruise speed	125 mph	193 km
No. of passengers +1 pilot	4	
Max. gross weight, fuel included	lb	kg
Internal load	3200	1452
External load	3350	1520
Fixed floats	3000	1361
Operational weight	lb	kg
IFR N/A		
VFR	1750	794
Useful load	lb	kg
Max. internal load	1450	658
Max. external load	1200	545
Fuel type		JP 1, JP 4, JP 5

Fuel capacity	L	kg	U.S. gal.	Imp. gal.	lb
(standard tanks)	273	212	76	63	491

Fuel consumption	78 kg/h	100 L/h
	172 lb/h	22 gal/h
Range	350 SM	565 km
Max. endurance	2.7 h	
Max. hook load	1200 lb	544 kg
Max. sling speed		Varies with load
Aux. fuel capacity (when equipped)	78 imp. gal	354.5 L
	608 lb	276 kg

Appendix B
Equipment Designs and Costs

Equipment Designs and Costs

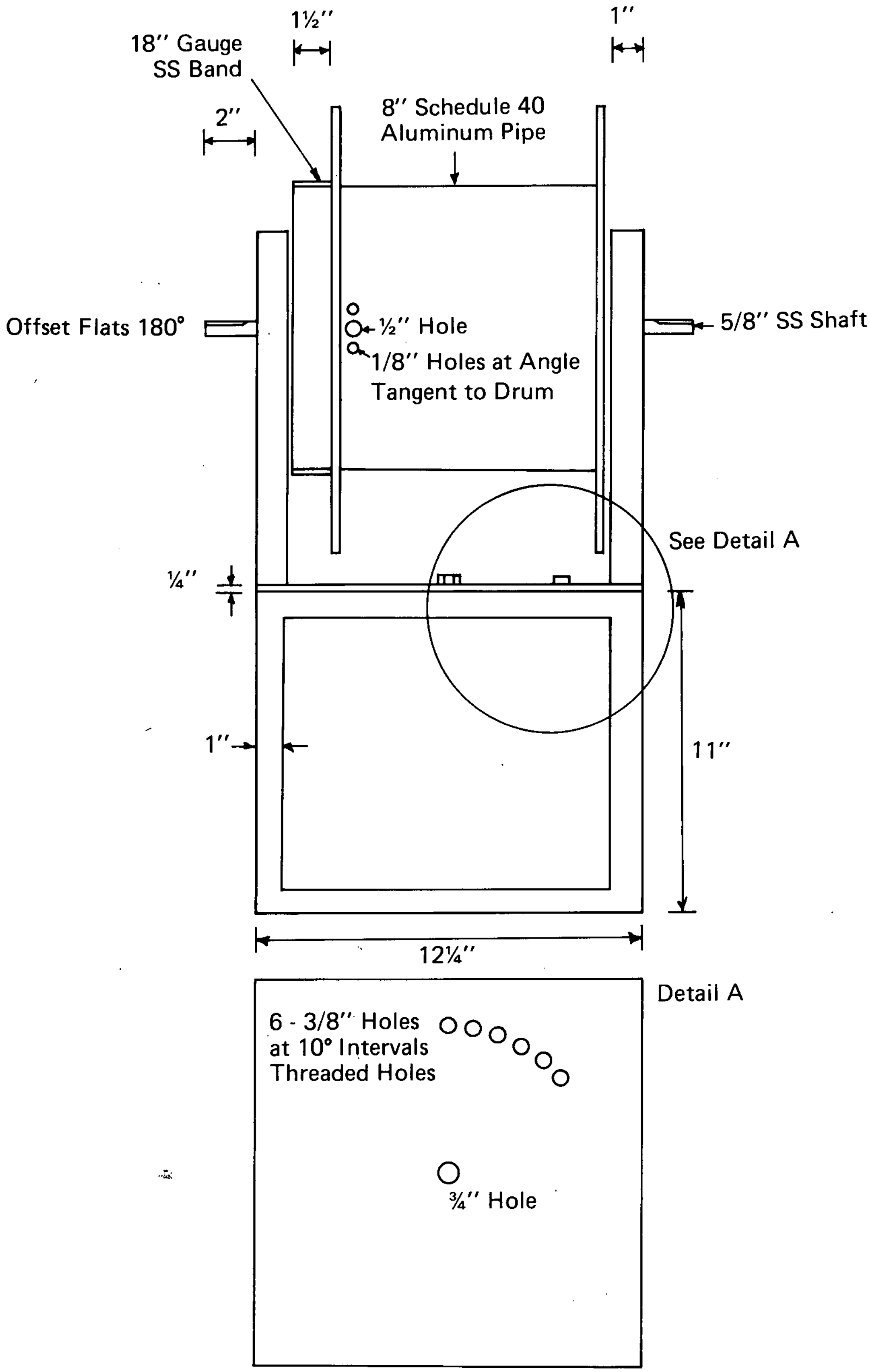
Table B-1 summarizes the initial cost of equipment. The figures following the table show the equipment design.

Table B - 1. Initial Cost of Equipment (1982 dollars)

Mode	Cost (thousands $Can.)
Summer	
Winch	1.1
Wire and meter block	1.0
CTD	8.0
Translator	5.0
Computer	3.0
Chemistry sampling gear	1.5
Tools	0.2
	19.8
Winter (additional)	
Winch base (ice)	0.3
Ice chisels	0.2
Ice auger and spares	1.0
Survival gear	1.0
Special clothing	0.8
	3.3

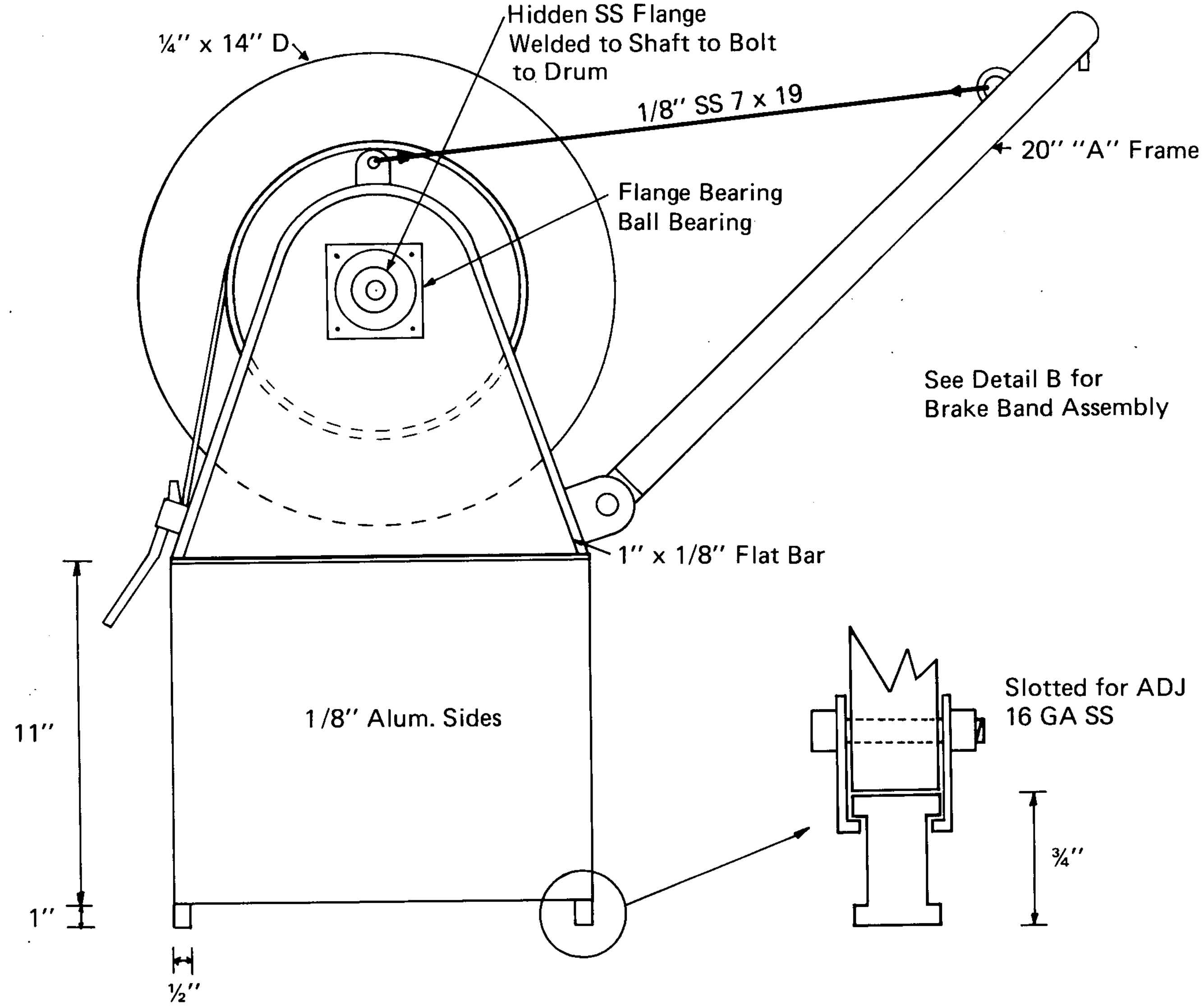
AIRPLANE HAND WINCH

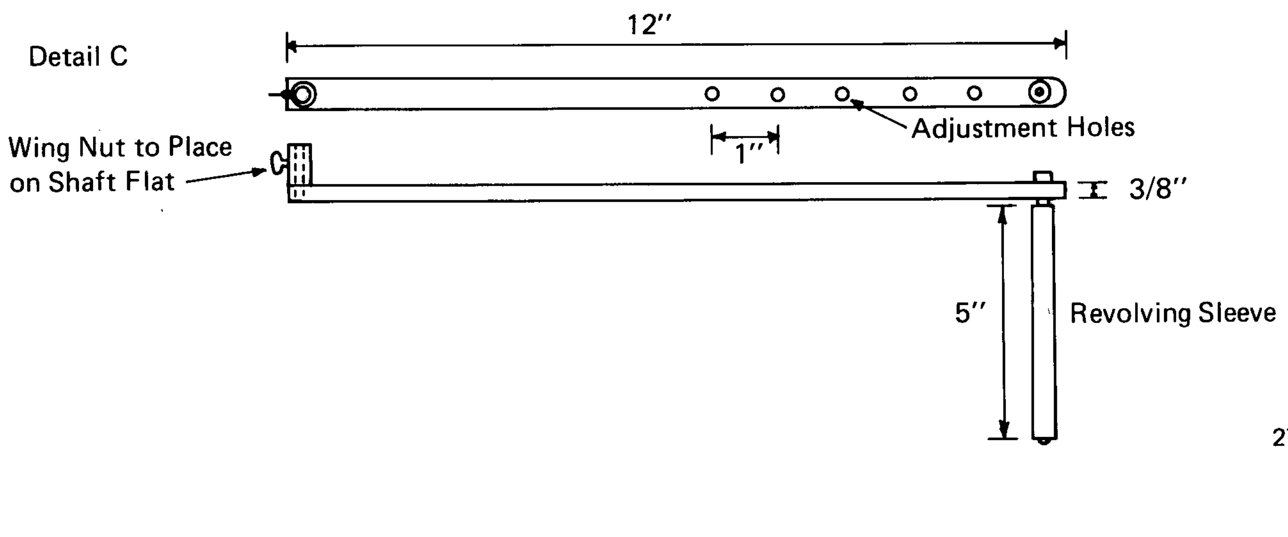
- FACE VIEW -



AIRPLANE HAND WINCH

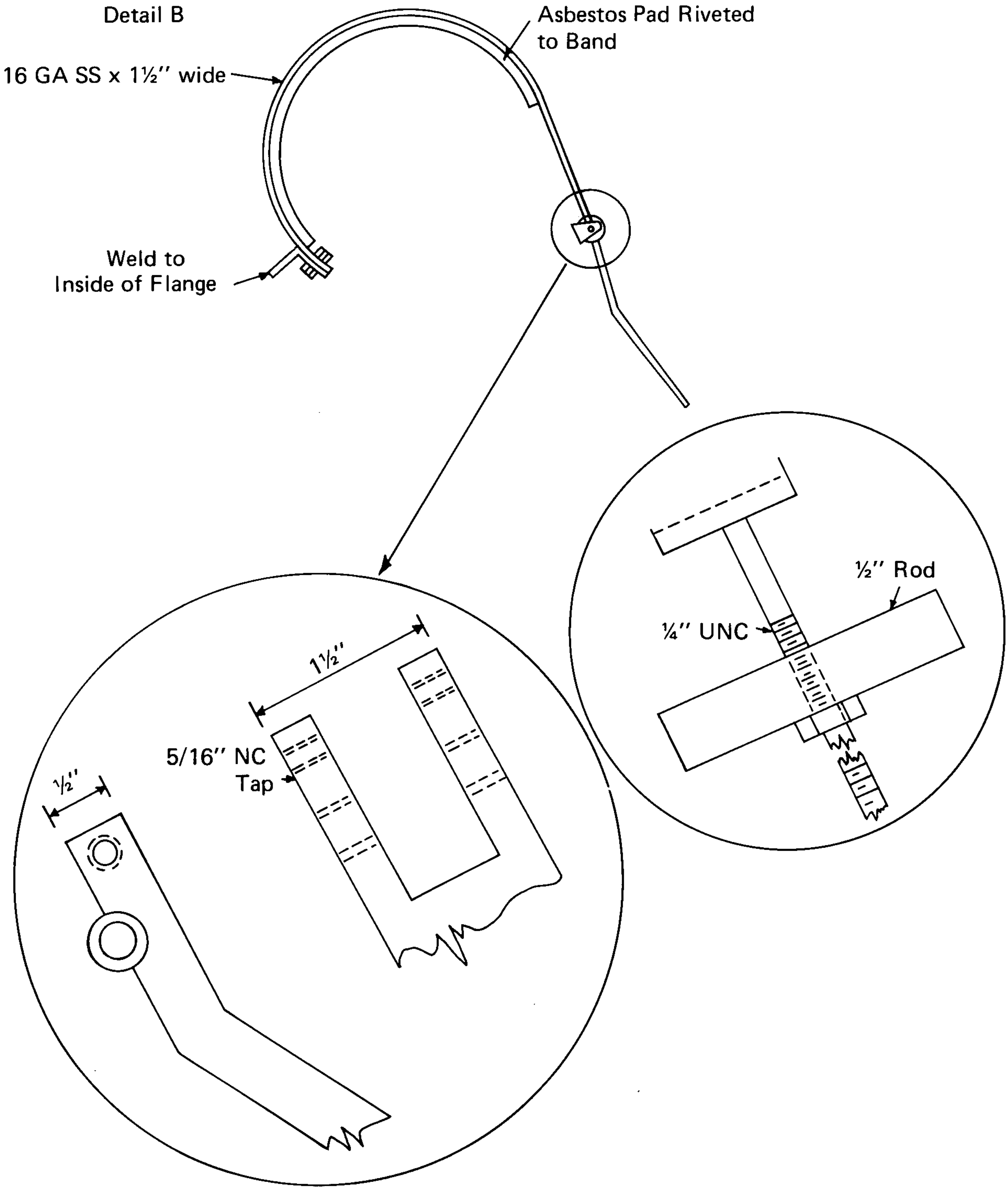
- SIDE VIEW -





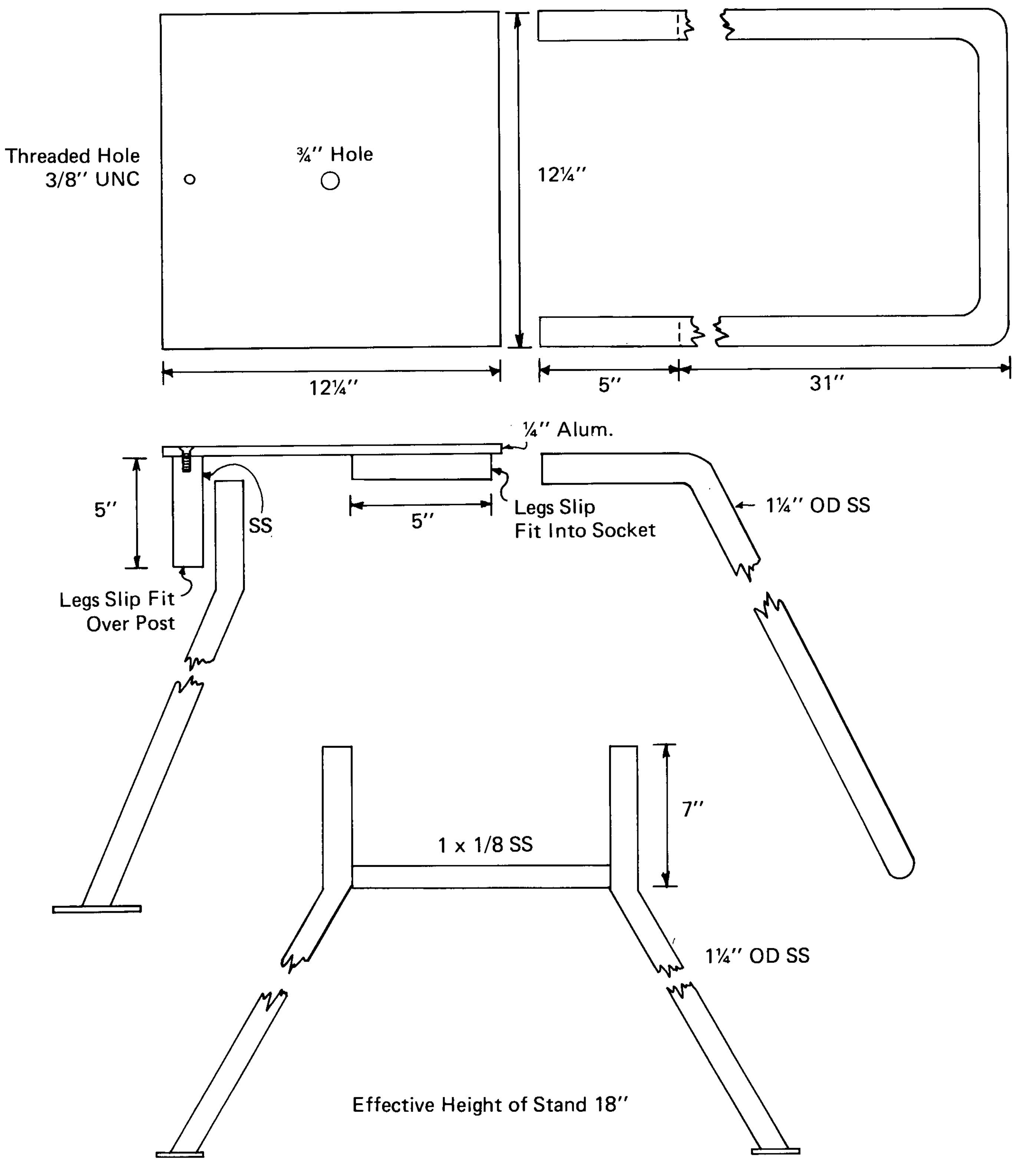
AIRPLANE HAND WINCH

– BAND BRAKE DETAIL –

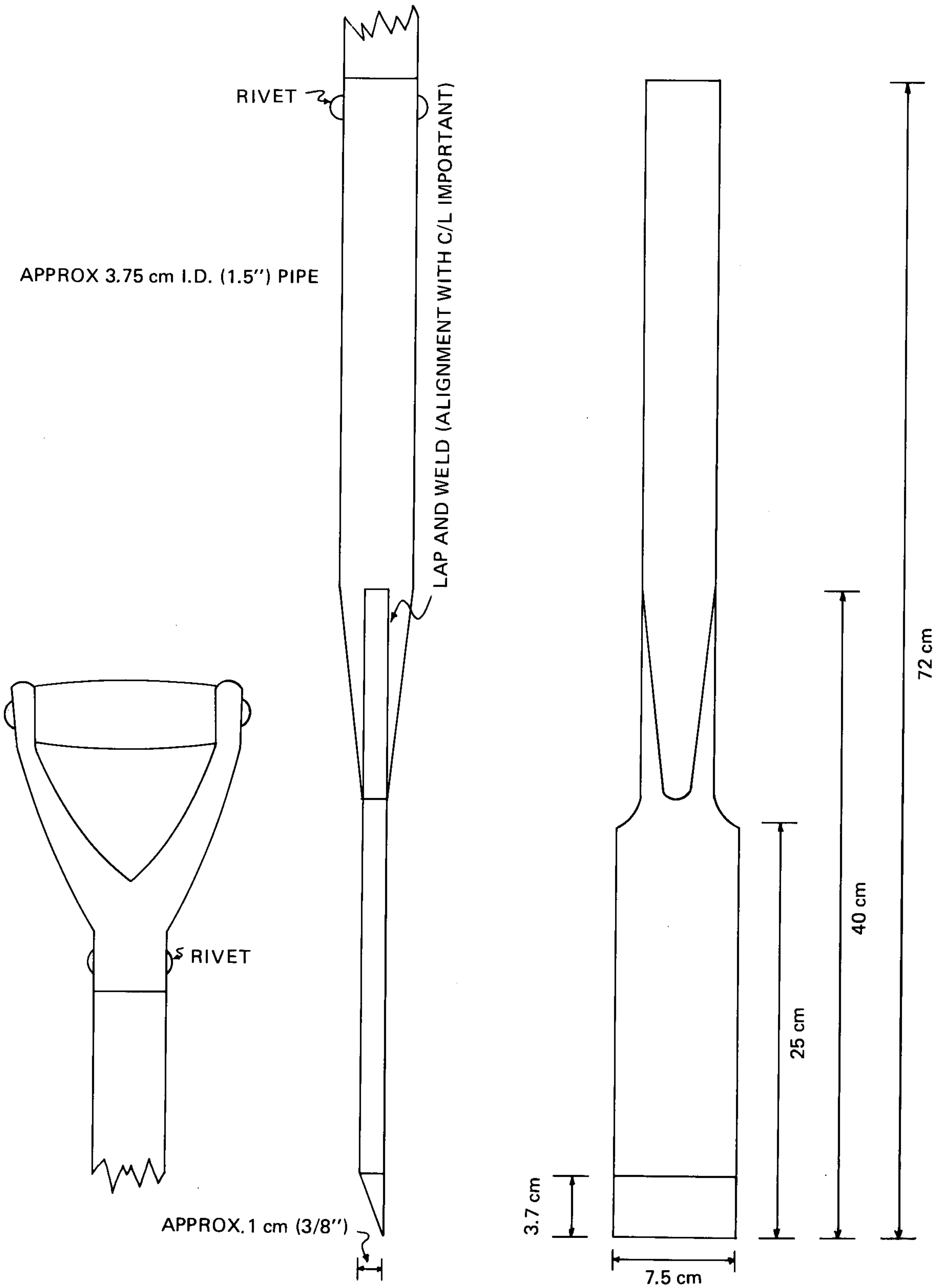


AIRPLANE HAND WINCH

- ICE BASE -



- ICE CHISEL -



BLADE: 1 x 7.5 x 40 cm TOOL STEEL HEAT TREATED TO ROCKWELL C58 - ELECTROETCH AND PAINT
HANDLE: 3.75 cm DIAM. STRAIGHT GRAINED ASH
OVERALL LENGTH COMPLETE: 2.0 m
WEIGHT: 5.0 Kg

Appendix C
Inventory of Equipment

Inventory of Equipment

SUMMER INVENTORY: C206 AIRCRAFT

Hand winch, 1/8 in. -7 × 19 stainless steel wire (365 m), G.M. Mfg. meter block for 1/8 in. wire

Swivel base for winch adapted to seat track

3 Niskin bottle racks with base for seat track and removable bottle tray

3 2.5-L Niskin bottles and 4 messengers

2 Coleman plastic coolers with sample bottles, dissolved oxygen bottles and chemical reagents

Applied Microsystems CTD-12 (in box): wrench, bar, alcohol, spares, case bolts, belts, start plug, tape, silicone grease

Tool box with usual mechanical tools: cable thimbles, Nicopress tool, shackles

0.5-m zooplankton net

Secchi disk

Surface thermometer -8°C to 32°C (0.05° divisions)

WINTER INVENTORY OF EQUIPMENT

Hand winch (as summer) with dismountable ice base (Fig. 6).

3 Niskin bottle racks with bottles and 4 messengers

CTD with box and spares – 2 bottles of alcohol

1 Cooler for chemistry and 1 dissolved oxygen bottle box

Tools

Stihl ice drill with spare auger flight, cutter and spare fuel

1 Custom ice chisel

Survival pack (sleeping bags, tent, stove, food, first aid kit)

Snow shovel