'SKY-HOOK' ANTENNA for ARCTIC COMMUNICATION

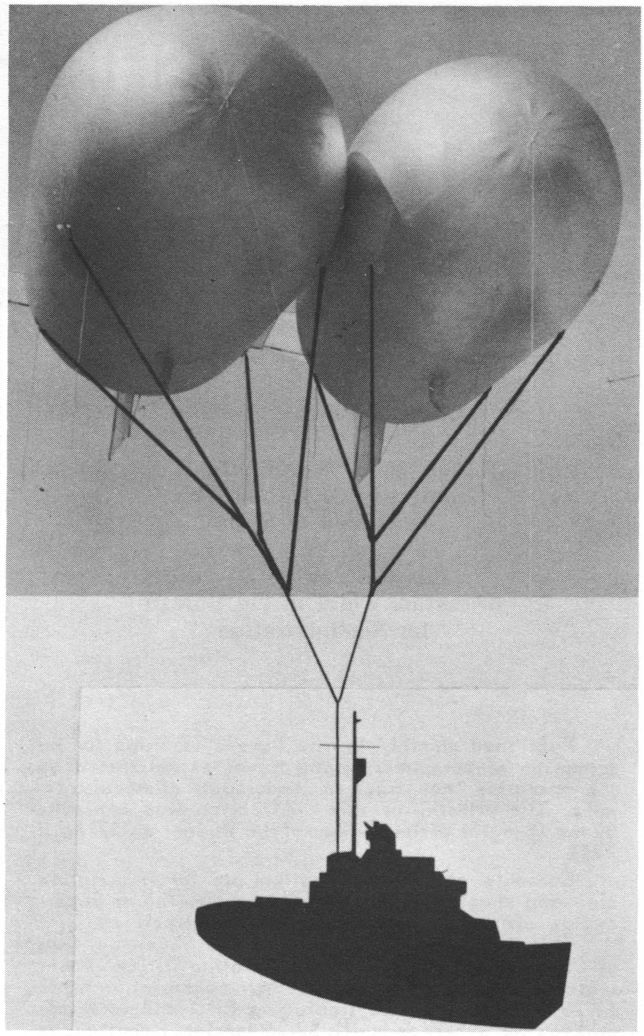


FIGURE 1. Two type JX-7 balloons are coupled for added lift to support the *GLACIER*'s antenna.

By John J. Doherty

Electronics Ship Division, Bureau of Ships

Much humor has been directed at the use of potential "sky-hook" antennas for practical shipboard communication. This humor, associated mainly with efforts to support a vertical wire long enough to approximate a quarter wave, has run the gamut from proposals for evaluation of the "Indian rope trick" to serious consideration of the use of helicopters to support the antenna cable. In fact, a manufacturer recently demonstrated a remote-controlled miniature helicopter just for this purpose.

The humor, however, took a more serious turn with the advent of the icebreaker *GLACIER* (AGB-4). This ship has been equipped with a vertical or "sky-hook" antenna, which it is hoped will prove effective in Arctic communication.

Since icebreakers often operate in isolated areas remote from land-based relay stations, the implied requirement for reliable direct communications is about 1,500 miles. Anyone familiar with propagation problems in extreme northern latitudes will appreciate the severity of this requirement. Such phenomena as ionospheric blackouts, sunspots, electromagnetic storms, and high ambient noise levels at receiver sites make communication in these areas extremely difficult.

Use of Low Frequencies Suggested

Experiments conducted in the Arctic suggested the use of the lower frequencies around 200 kilocycles to obtain maximum reliability. It was decided that the optimum length of antenna required to transmit at these low frequencies would be 1,200 feet. Obviously, since no icebreaker was capable of sustaining a horizontal wire of this length, the only alternative was a vertical wire or "sky-hook" antenna.

During the last few years, the Bureau has been experimenting with long range propagation studies in the Arctic in connection with the winter trips of the icebreakers *BURTON ISLAND* (AGB-1), *EDISTO* (AGB-2), and *ATKA* (AGB-3). Based on experience gained by Bureau engineers in efforts to raise and lower a vertical antenna aboard ship, a balloon-raised antenna system was designed for installation aboard the USS *GLACIER*. This system was developed by the Naval Research Laboratory under guidance of the electronics divisions of the Bureau of Ships.

Numerous lifting devices were first considered in efforts to raise 1,200 feet of wire vertically into the air. Barrage balloons, "Kytoons," and even helicopters were tried. After much deliberation, they were all discarded because of various physical, aerodynamical, and electrical deficiencies.

Zeppelin Type Balloon Needed

It was finally concluded that the zeppelin type balloon, rather than the spherical type, would be most suitable because of its inherently better static and dynamic lift characteristics. Here again, the desired zeppelin type balloon would require special material and design to maintain antenna vertical stability and to withstand extreme icing conditions and the buffeting of strong Arctic winds.

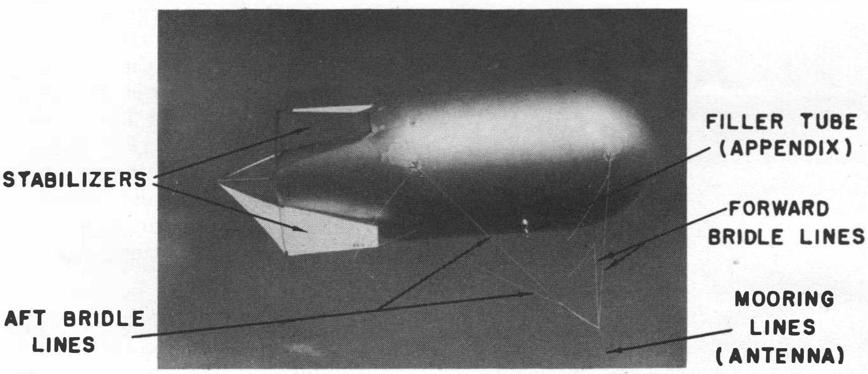
Accordingly, the Bureau of Ships initiated development of three new types of balloon to satisfy the variety of conditions normally encountered in the Arctic. Eight balloons, consisting of two type JX-9, two type JX-8, and four type JX-7A (figures 1 and 2), were developed and procured from the Jalbert Aerological Laboratory, Boca Raton, Fla., for use aboard the *GLACIER*. Performance data for these balloons, based on actual measurements, are listed in the accompanying table.

JALBERT AEROLOGY BALLOONS

	JX-7A	JX-8	JX-9
Length of envelope, empty	22'2''	28'0''	28'0''
Length of balloon, overall, empty	24'8''	32'0''	32'0''
Length of envelope, inflated without fins	19'9''	26'0''	25'0''
Length of balloon, inflated with fins	23'0''	30'7''	30'0''
Length of fin struts	9'2½''	8'11''	10'7''
Length of fin posts	3'8''	5'0''	5'0''
Diameter of envelope (max.)	7'0''	7'7''	9'3''
Gas capacity of envelope (cu. ft.)	600	870	1,225
Weight of envelope, without fin struts (lb.)	21	31½	38
Weight of fin struts (lb.)	2¾	2½	3
Weight of balloon fabric (oz. per sq. yd.)	5	5	5
Weight of balloon, gross (lb.)	23¾	34	41
Free lift of balloon, inflated with helium (lb.)	13¼	20	35
Gross lift of balloon (lb.)	37	54	76
Lift of helium (lb. per 100 cu. ft.=6.2)			
Free lift of balloon per 100 cu. ft. of gas capacity	2.21	2.3	2.86
Pounds increase in free lift per ft. increase in length at maximum diameter	1.63	2.07	3.17
Container size (in.)	12''x12''x24''	12''x18''x24''	12''x18''x24''

Under supervisory guidance of the Bureau, parallel investigations were undertaken by the Naval Research Laboratory to develop a suitable launching system consisting of an antenna cable, lightweight insulators, a power-operated winch, and handling devices to prevent entanglement of the balloon with the ship's rigging and antenna systems.

FIGURE 2. Type JX-7 balloon.



Spooling the Cable

In early balloon experiments a small variable-speed winch, powered by a 1/3-horsepower electric motor, was used to spool the antenna cable. On shipboard, under actual Arctic conditions, a 1-horsepower motor was used. Further experimentation revealed that a 1,150-cubic-foot balloon could be retrieved safely at speeds up to 360 feet per minute, which is considered sufficient to accommodate any anticipated emergency condition.

It was established later that spooling equipment would require a

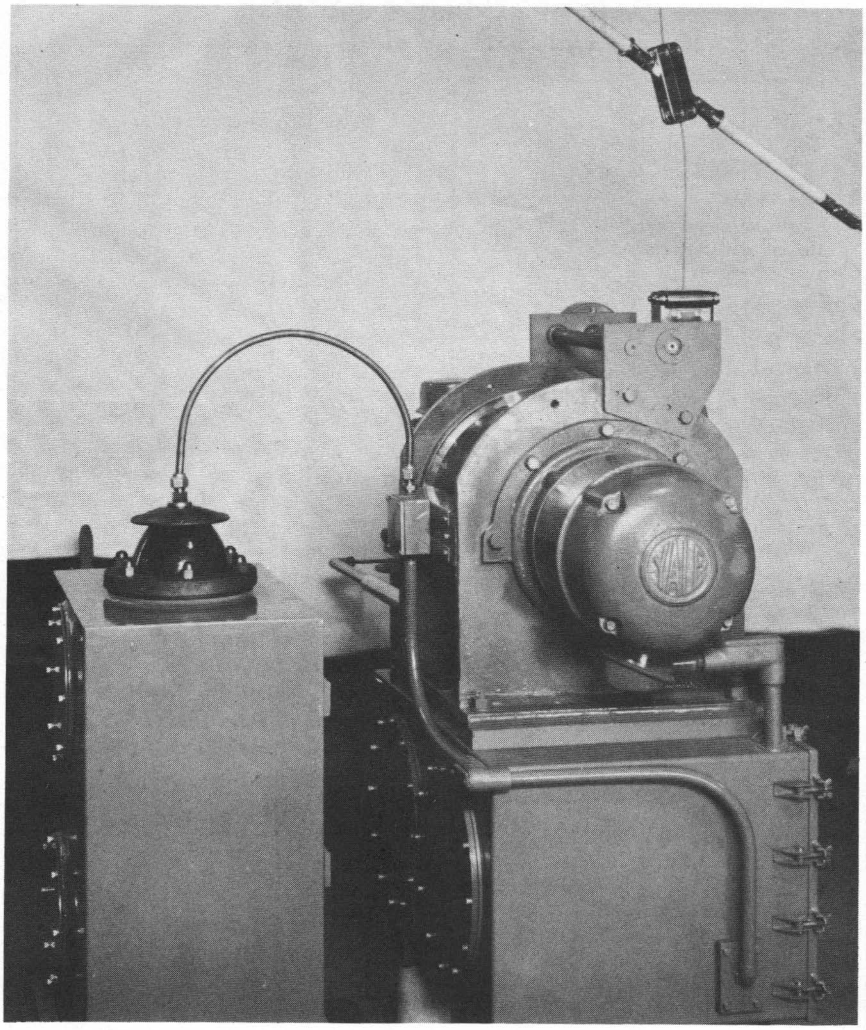


FIGURE 3. Spooling equipment operated satisfactorily even with three balloons attached to the antenna cable.

2-horsepower electric motor to withstand sudden overloads and stresses. The motor supplied with the system for the *GLACIER* is capable of withstanding cable tensions up to 150 pounds and provides for reversible multispeed operation at 90, 180, and 360 feet per minute. It includes a level-wind mechanism and a magnetic brake to stop and hold the cable where required. For operational safety the control switch is operated from a remote point outside the guard rail with the handle insulated to withstand 20,000 volts. This system is intended to operate at temperatures down to -30° F. The entire spooling equipment also requires insulation from ground to withstand RF potentials up to 20,000 volts.

Since there were no commercial spooling equipments to fulfill these requirements, it was necessary to use standard stock parts from several commercial power winches and modify them to conform to the established requirements. The spooling equipment which was developed (figure 3) showed very satisfactory operating characteristics even with three balloons attached to the antenna cable. The cable is connected electrically at each end of the supply spool by a slip ring and brush assembly.

Switching by Remote Control

The on-off switching equipment shown in figure 4 is designed for mechanical remote control to protect the operator from high voltages. RF power is fed to the antenna through a curved section of copper tubing which is connected electrically to the spooling drum. Three-phase power leads to the drive motor are run inside this copper tubing to reduce RF pickup.

Provision for automatically grounding the reel and antenna when three-phase power is applied to the winch drive motor is in-

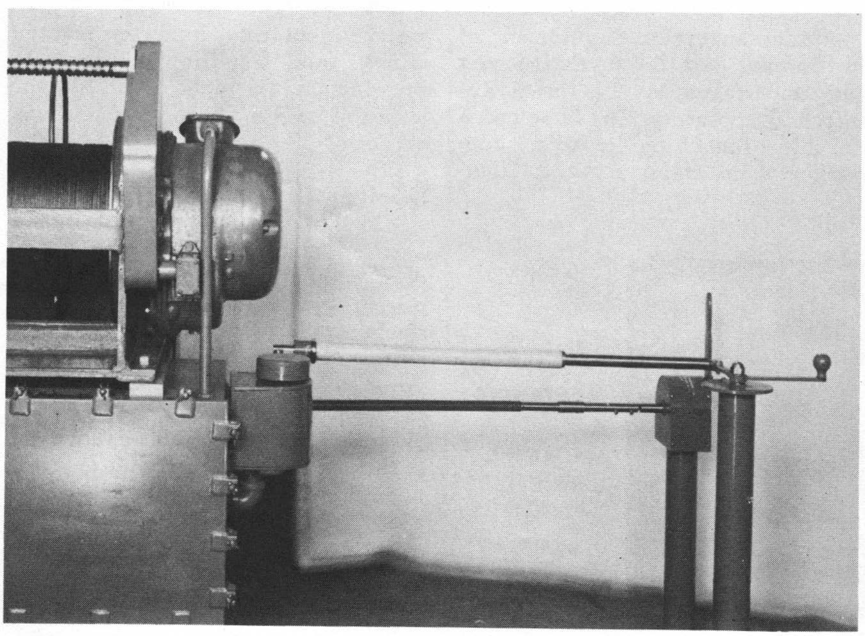


FIGURE 4. On-off switching equipment (right) is designed for mechanical remote control.

corporated into the system. This feature prevents RF or static high voltage from appearing on the reel or feeding back through power cables during launching or retrieving of the balloons. There is also an interlocking device which prevents an open circuit on the antenna when the antenna disconnect switch is open. On board the *GLACIER* all deck-mounted components are enclosed within protective guard rails with remote transmitter control for additional safety to the operator.

Launching and Retrieving

The over-all launching and retrieving system consists of three pulleys--one at the masthead (figure 5), one at the forward end of the top of the hangar deck, and one at the aft end of the top of the hangar deck. These pulleys are connected by an endless manila or nylon rope to form a triangle, with the antenna trolley attached firmly to the hypotenuse of the triangle.

This arrangement minimizes the danger of antenna entanglement in the ship's rigging, and allows the pivot point of the antenna cable to be shifted to a clear open space during launching and retrieving. It also permits flying the balloons from the topmost position on the mast, eliminating the hazards of entanglement with topside installations.

In operation, the antenna cable passes from the supply spool between rollers in the antenna trolley to an insulator attached to the bridle of the balloon. The antenna trolley is firmly attached by insulators to the endless guide rope. The antenna trolley may be positioned at any location between the mast and the aft end of the flight platform by simply rotating the endless rope to the desired position.

Several Cable Types Selected

Several cable types have been selected for experimental use as an antenna in this system in order to determine the most practical for general shipboard use. The optimum cable requires specific characteristics such as flexibility, lightness of weight, adequate breaking strength, and sufficient peripheral area to keep the RF potential gradient to a reasonable value so as to minimize corona loss.

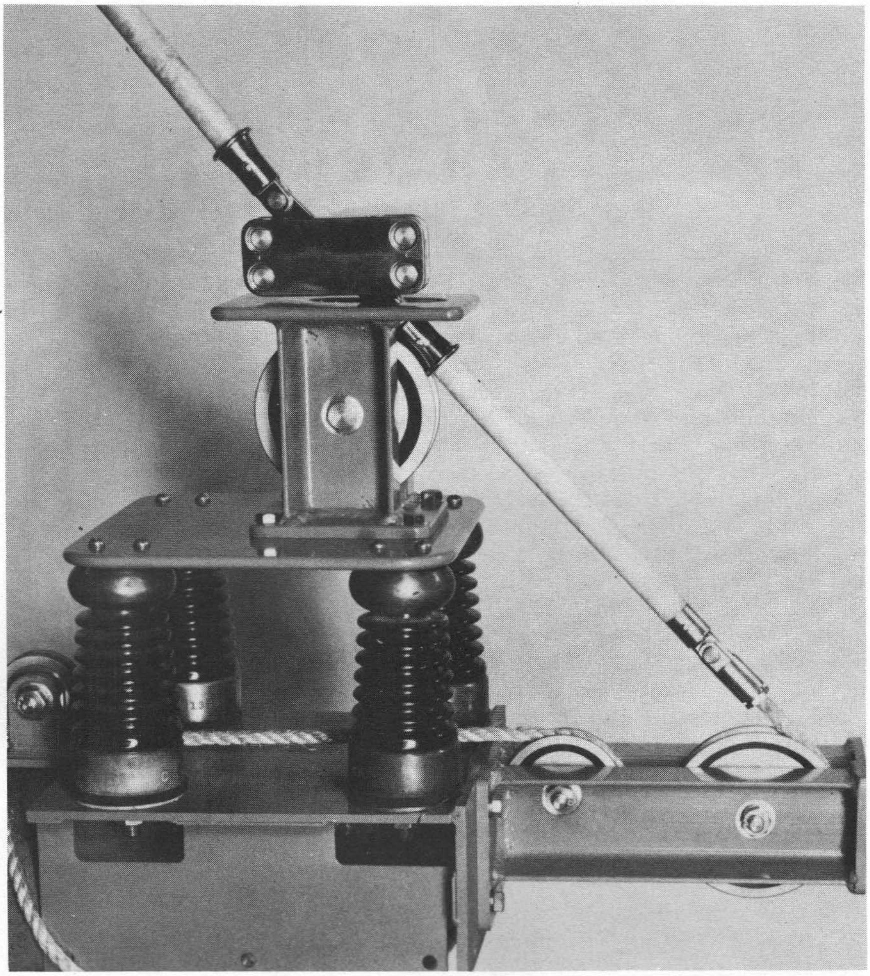


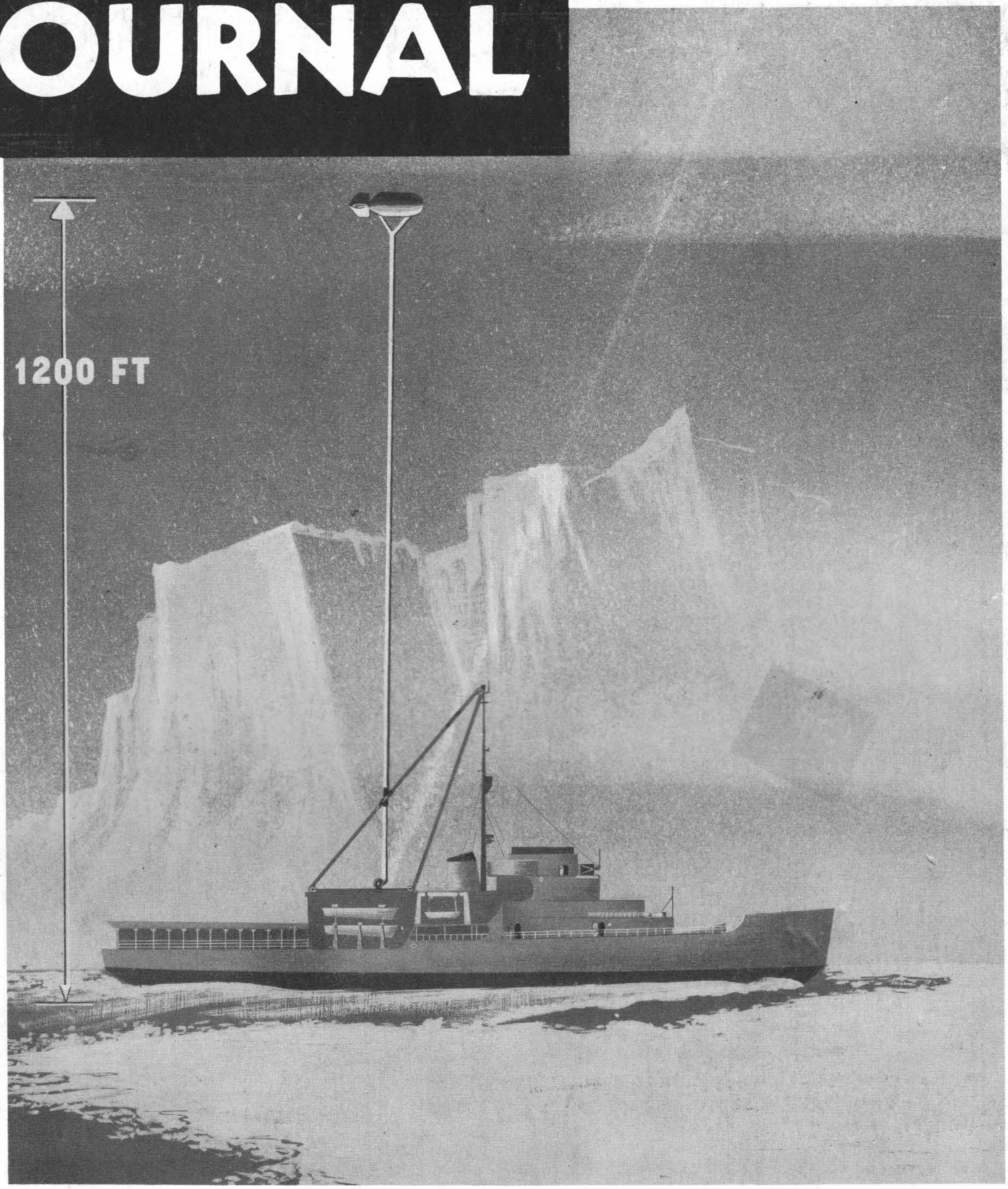
FIGURE 5. Masthead pulley is one of three pulleys in the launching and retrieving system.

Representative of the desired cables, three 1,250-foot lengths of 6 by 6 by 7 phono-electric bronze wire rope were procured and will be supplied for use aboard the *GLACIER.* This cable has a nominal diameter of 0.125 inch with nylon strand cores. It has a breaking strength of approximately 335 pounds and weighs about 20 pounds per thousand feet. In preliminary development testing, several types of aluminum and stainless steel wires, which have inherently good conductivity and corona resistance properties, were tried, but they were finally discarded because of poor abrasion resistance and kinking.

Anticipated antenna system efficiencies have been calculated and plotted; i.e., antenna resistance versus frequency, antenna reactance versus frequency, and antenna system efficiency and feed point voltage versus height. These data indicate that for a transmitter power amplifier output of 2 kilowatts and a radiated power of 1,500 watts, the optimum antenna cable height should be 1,200 feet. Under these conditions, it is expected that the balloon-elevated antenna system will provide a reliable communication range of 1,500 miles under Arctic conditions.

The "sky-hook" antenna system aboard the *GLACIER* also will be used for aerological studies and weather observations.

BUREAU OF SHIPS JOURNAL



JULY 1955