# Construction and Operation of a Two-place Diver's Sled

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## Introduction

Fisheries gear researchers have employed scuba diver-operated sleds to evaluate towed fishing systems since the early 1950's. One of the earliest sled designs was a converted Stokes litter in which two divers sat tandem with the forward diver operating the diving controls (Sand, 1956). The litter was relatively easy to maneuver and provided a comfortable platform for observing operational fishing gear. However, the use of underwater photographic equipment to document gear performance was difficult due to the limited mobility of the observer-cameraman.

A new two-place diver's sled, designed specifically for underwater cinematography, was introduced in the late 1950's (Hold, 1960). This sled allowed the divers to lie side-by-side which greatly reduced water resistance. The sled pilot occupied the port position, and the observer-cameraman, facing either forward or aft, occupied the starboard position. This design offered two advantages over the converted Stokes litter: 1) It was more maneuverable due to the location of its towing point and 2) it facilitated the use of underwater photographic equipment. Disadvantages of this steel sled were that it was heavy, subject to corrosion, and accessory flotation tanks were necessary for positive buoyancy.

The weight and corrosion problems were solved in the late 1960's by replacing the steel frame and wooden control surfaces with aluminum[1]. The lighter weight and reduced accessory flotation requirements made the aluminum two-place diver's sled more maneuverable than the steel sled. Because of its excellent handling and performance characteristics, it has become a standard piece of equipment for use in towed fishing gear evaluations by the Harvesting Systems Branch, National Marine Fisheries Service, Mississippi Laboratories, Pascagoula Facility.

In addition to fishing gear research, a number of other applications for diver operated sleds have evolved, including: Evaluation of towed instruments; biological, archeological, and geological surveys; and search and recovery operations. This report provides the information necessary to construct and operate a two-place diver's sled. It is not, however, intended to replace instruction or field training in sled operations.

## Construction

Constructed entirely of aluminum, the two-place diver's sled has an overall length of 2.3 m (92¼ inches) and a width of 2.2 m (87¾ inches) (Fig. 1). Fully rigged, the sled's out-of-water weight is about 41 kg (90 pounds). Watertight welds and two attached side floats provide positive buoyancy.

### Materials Required

1) 87 feet 6 inches of 1-inch internal diameter (ID) schedule 10 aluminum pipe
2) 1 foot 10 inches of 1⅜-inch ID schedule 10 aluminum pipe
3) Four 26½- by 15½-inch sheets of 3/16-inch aluminum
4) Two 46- by 14-inch panels of #36 nylon webbing
5) One spool of #42 (or #60) nylon twine
6) One ¾-inch shackle
7) One ⅝-inch swivel
8) Two 14- by 6-inch plastic (or styrofoam) floats
9) 12 inches of 3.8-inch aluminum rod
10) Two 2-link sections of 3/16-inch chain
11) Two 3/16-inch lap links
12) Two 3/16-inch shackles
13) Two #3 snap hooks
14) Diver depth gauge
15) Bicycle flag and staff

### Sled Frame—Top Section

The top section of the sled frame is constructed from 1-inch ID aluminum pipe (Fig. 2). The two outside frame members measure 84 inches long and are connected at the after end by a 50-inch pipe section. Forward, they are connected by two 19-inch pipe sections and a central "Y" section. The "Y" section is made with two 23½-inch pipes which join with a central pipe measuring 64 inches long. The other end of the central pipe is attached to the middle of the 50-inch pipe. A 3-inch pipe is attached between the two "Y" members to later serve as an attachment point for a towing swivel.

### Sled Frame—Bottom Runners

The bottom runners are made from two 110½-inch lengths of 1-inch ID alumi-

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[1]L. H. Ogren. 1983. National Marine Fisheries Service, SEFSC, 3500 Delwood Beach Drive, Panama City, FL 32407. Personal commun.

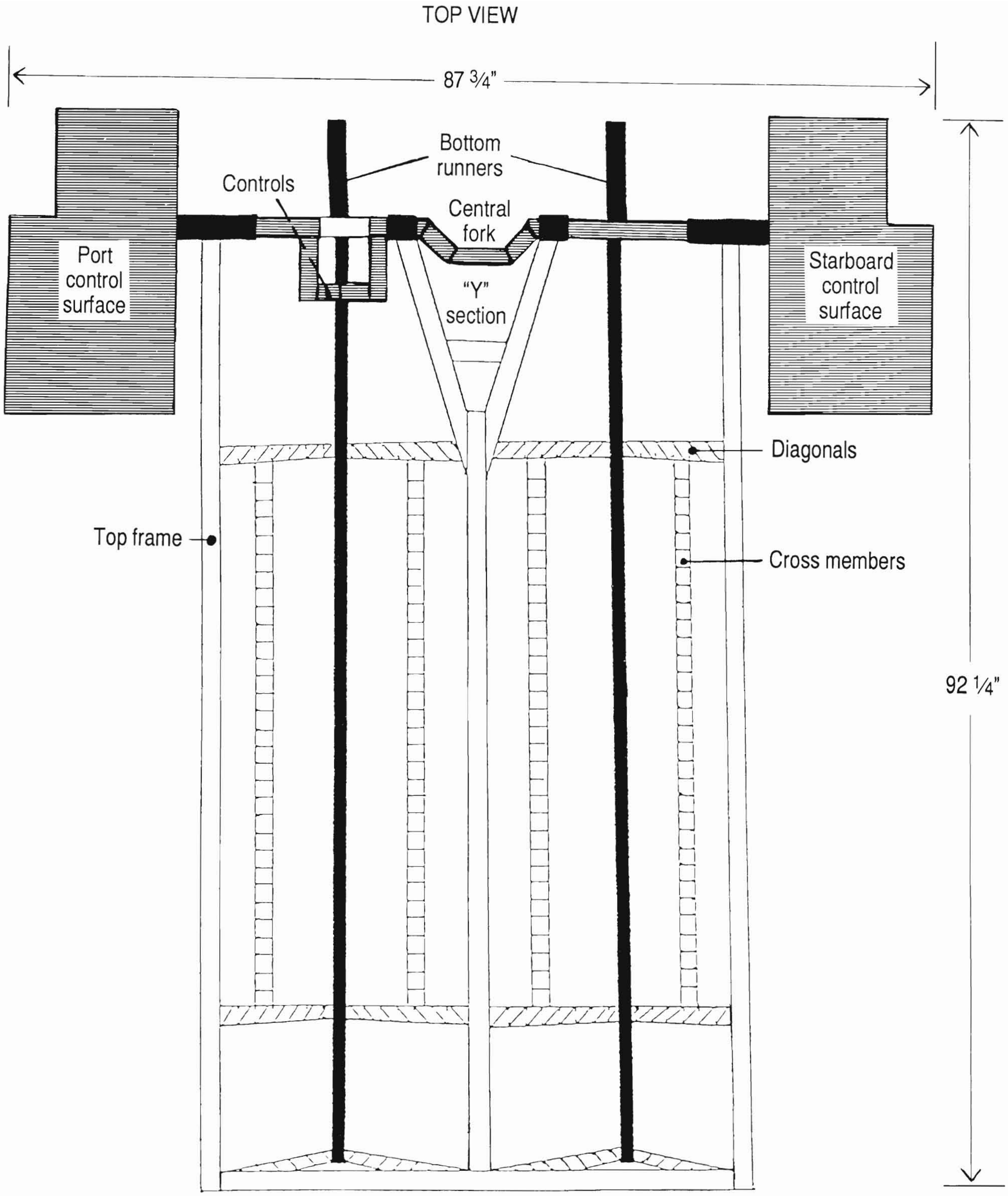


Figure 1.—The two-place diver's sled.

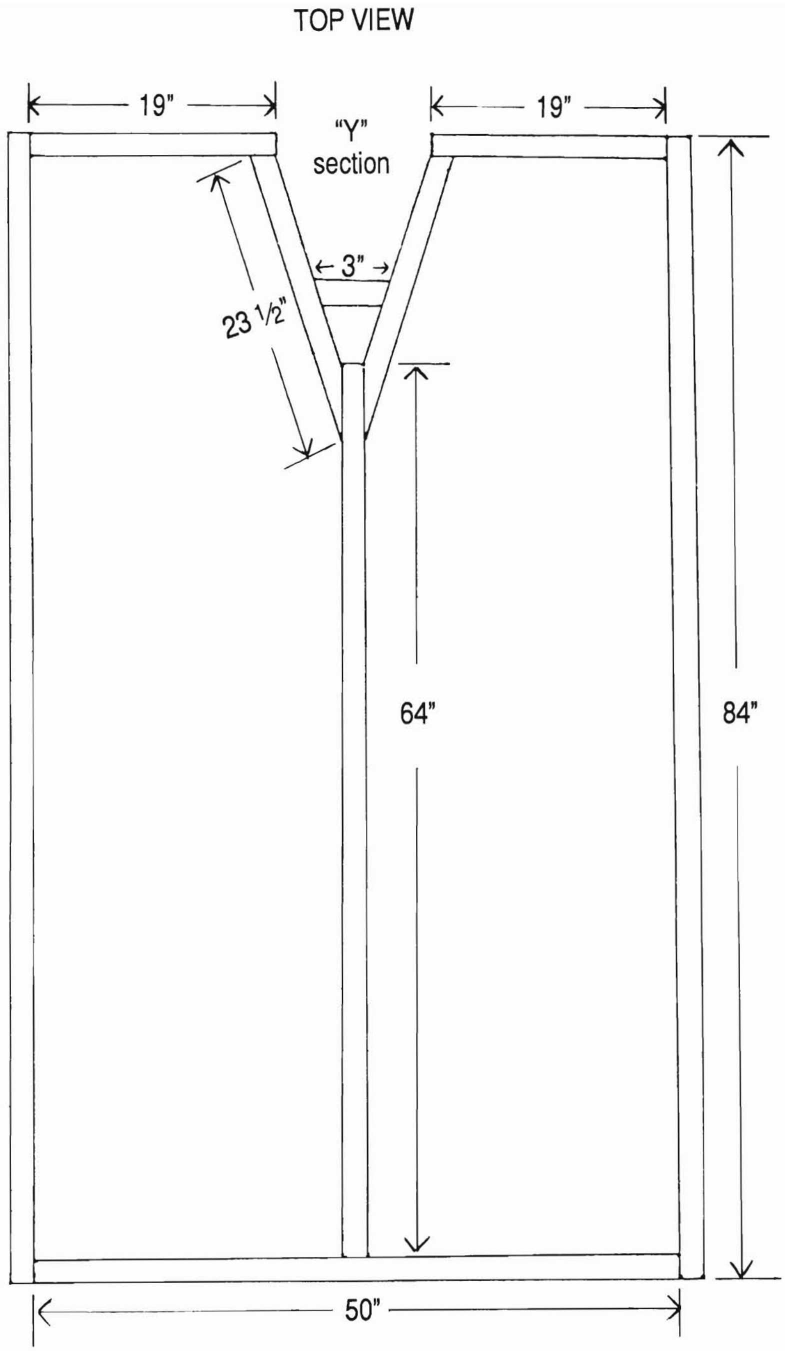


Figure 2.—The top section of the sled frame.

num pipe (Fig. 3). The leading end of each pipe is bent into a half circle with an inside diameter of 14½ inches. The runners are attached 9½ inches inward on the two 19-inch forward pipe sections of the top frame.

## Sled Frame—Diagonal and Cross Members

There are 12 diagonal members (Fig. 4). Six outside diagonals attach between the runners and the outside top frame, and six inside diagonals are attached between the runners and the middle pipe of the top frame. The outside diagonals are 17 inches long, and the inside diagonals are 21 inches long. They are attached at three points along the sled frame. The first set of four (two outside and two inside diagonals) is attached to the after end of the sled. The next set is attached 17 inches inward, and the last set is attached 62¼ inches inward from the aft end of the sled. Four 45¼-inch cross members are attached between the forward and middle sets of diagonals. The outside cross members are attached 6½ inches down from the outside top section, and the inside cross members are attached 8¼ inches down from the middle pipe of the top section.

## Control Surfaces

Two pieces of $\frac{3}{16}$-inch aluminum sheeting measuring 26½ inches × 14 inches are used to make the top and bottom of each control surface (Fig. 5). A section 9¾ inches long and 3¾ inches across is removed from each sheet. A 1-inch ID pipe is placed between the two sheets and aligned with the edge of the 3¾-inch cut. A 24¾-inch pipe is used for the port control surface, and a 39¼-inch pipe is used for the starboard control surface. The two sheets are welded to the pipe and bent equally top and bottom to join the two ends. Side pieces are then fitted between the top and bottom sections.

## Controls

The guides, which allow the control rods to rotate freely, are made with 1⅜-inch pipe (Fig. 6). Two of the guides are 8 inches long, and two are 3 inches long. The 8-inch guides are attached with 3 inches of outside overhang to the forward port and starboard sides of the top sled frame. The 3-inch guides are attached with their inner edges even with the inside of the "Y" section. The 24¾-inch pipe, with the port control surface attached, is inserted through the 8-inch guide on the port side of the sled and attached to the port control handle assembly. The control handle assemblies (port and starboard) consist of a 4¼-inch top pipe, an

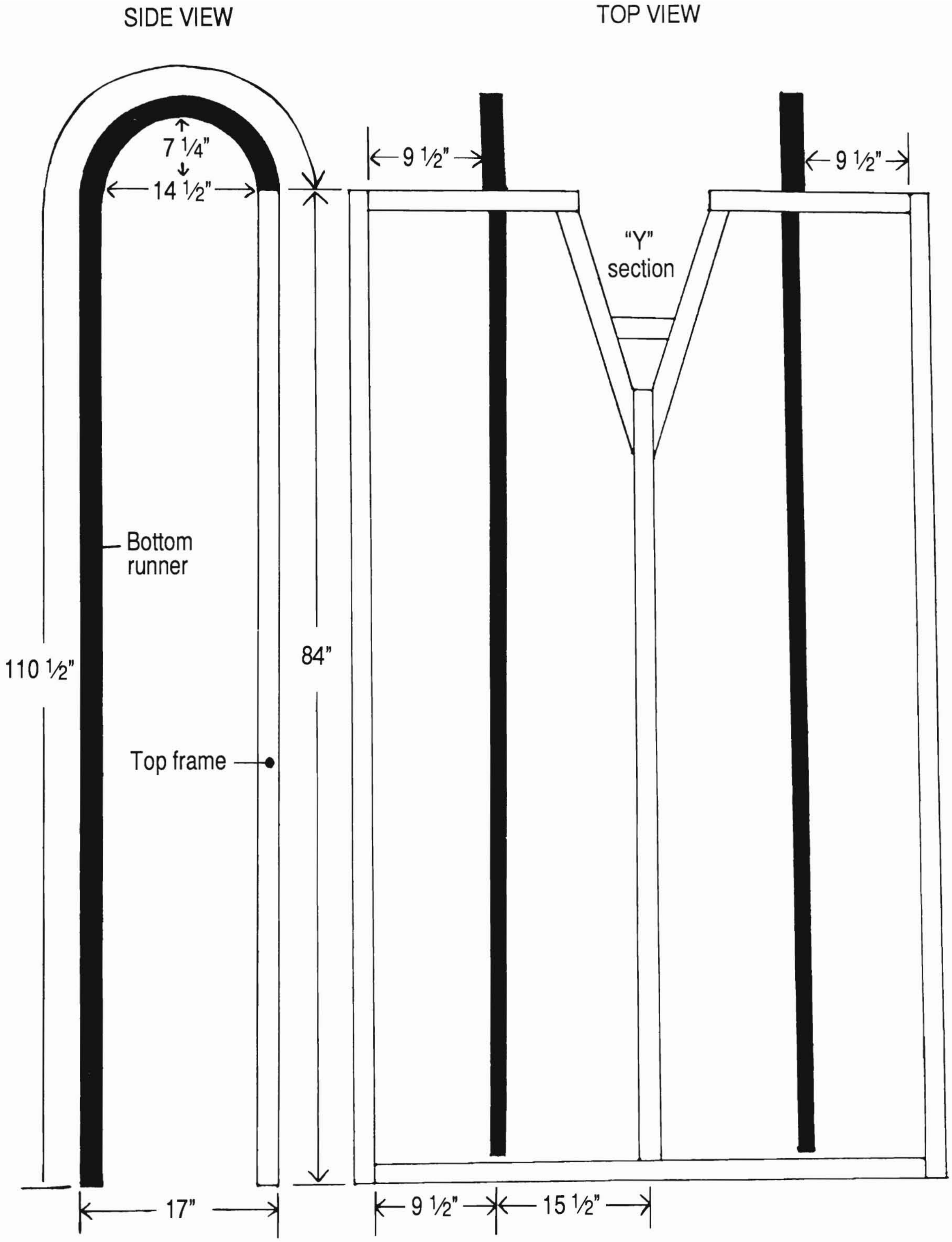


Figure 3.—The bottom runners of the sled frame.

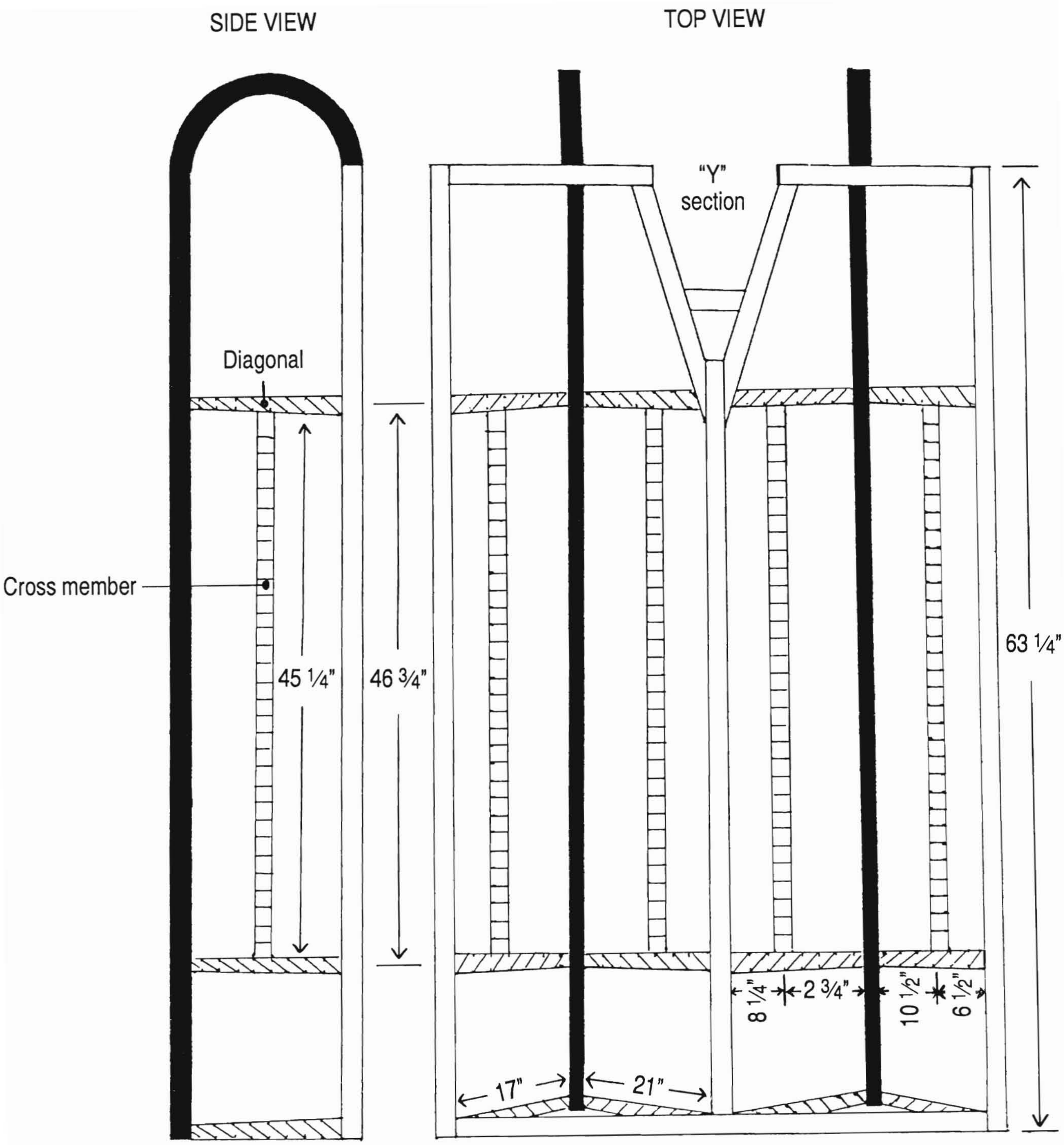


Figure 4.—Diagonals and cross-members of the sled frame.

8-inch down pipe and a 6-inch handle. The 39¼-inch pipe of the starboard control is inserted through the 8-inch and 3-inch guides and is attached to a central fork. The fork has 14¼-inch sides and a 6½-inch base. A 7-inch pipe is inserted into the port 3-inch guide to connect the fork and starboard control handle assembly.

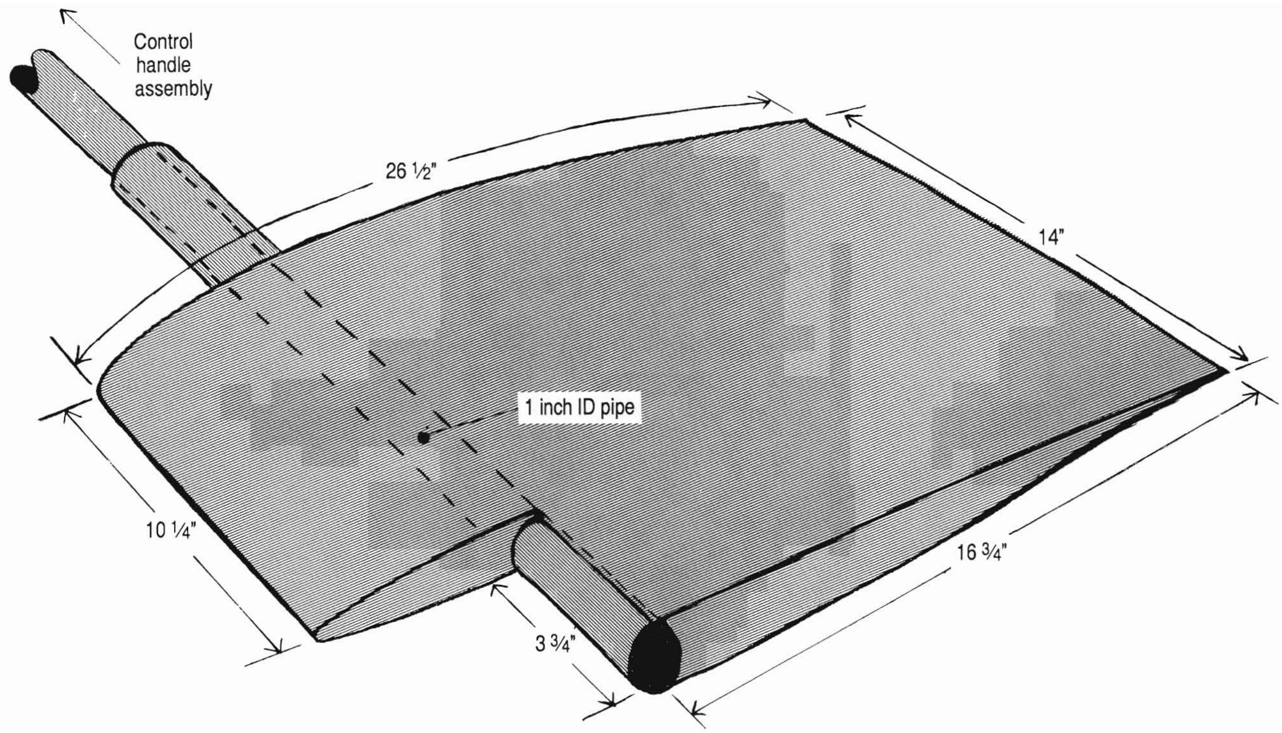


Figure 5.—Port control surface.

## Accessories

Two nylon webbing panels, each measuring 46 × 14 inches, form belly pads for the divers. They are attached with nylon twine between the inside and outside cross members on the port and starboard sides. For increased support, $^3/_{16}$- to ¼-inch line can be woven through the front and back edges of the belly pad and attached between the cross members.

Two 6- × 14-inch floats are attached with line or webbing to the two outside forward diagonals between the top frame and outside cross members.

A ⅝-inch swivel is attached to the 3-inch pipe between the top frame "Y" section with a ¾-inch shackle to provide a twist free attachment point for the tow line.

Sled control restraint (Fig. 7) keep the sled in an upright plane when towed at the surface without divers. They are constructed with three 4-inch pieces of ⅜-inch aluminum rod, each bent into U-shapes; two 2-link sections of $^3/_{16}$-inch chain; two $^3/_{16}$-inch lap links; two $^3/_{16}$-inch shackles; and two #3 snap hooks. Two of the 4-inch U's are attached with one end to the down pipe and the other end to the handle on both control handle assemblies. The third 4-in U is attached just above the center of the curve (bottom end of U at center of curve) on the bottom runner control side of the sled. The 2-link sections of $^3/_{16}$-inch chain are attached to the #3 snap hooks with the two $^3/_{16}$-inch lap links. These two chain and hook assemblies are attached to the 4-inch U on the bottom runner with the two $^3/_{16}$-inch shackles. The snap hooks are snapped into the two 4-inch U's on the control handle assemblies (one hook to each control) to hold the control surfaces in an ascent position (leading edge of control surfaces up).

A depth gauge, positioned so that it can be clearly viewed by the pilot, is mounted to the forward section of the top frame where the bottom runner attaches on the pilot's side. A bicycle flag staff, about 3½ feet long, and a flag are attached to either outside aft end diagonal. When the sled is on the surface, the flag should protrude at least 2 feet above the water.

If divers are to be towed long distances at relatively high speeds, a "water shield" (underwater counterpart to a windshield) can be attached. The shield can be constructed from clear Lexan or Plexiglass in an aluminum frame. It is attached to the forward part of the top frame.

## Operation

The sled's light weight and easy handling characteristics make it ideally suited for towing from almost any size vessel. The sleds we use have been towed from vessels as small as a 14-foot skiff powered by a 9 hp outboard motor, up to a 174-foot research vessel powered by two 800 hp

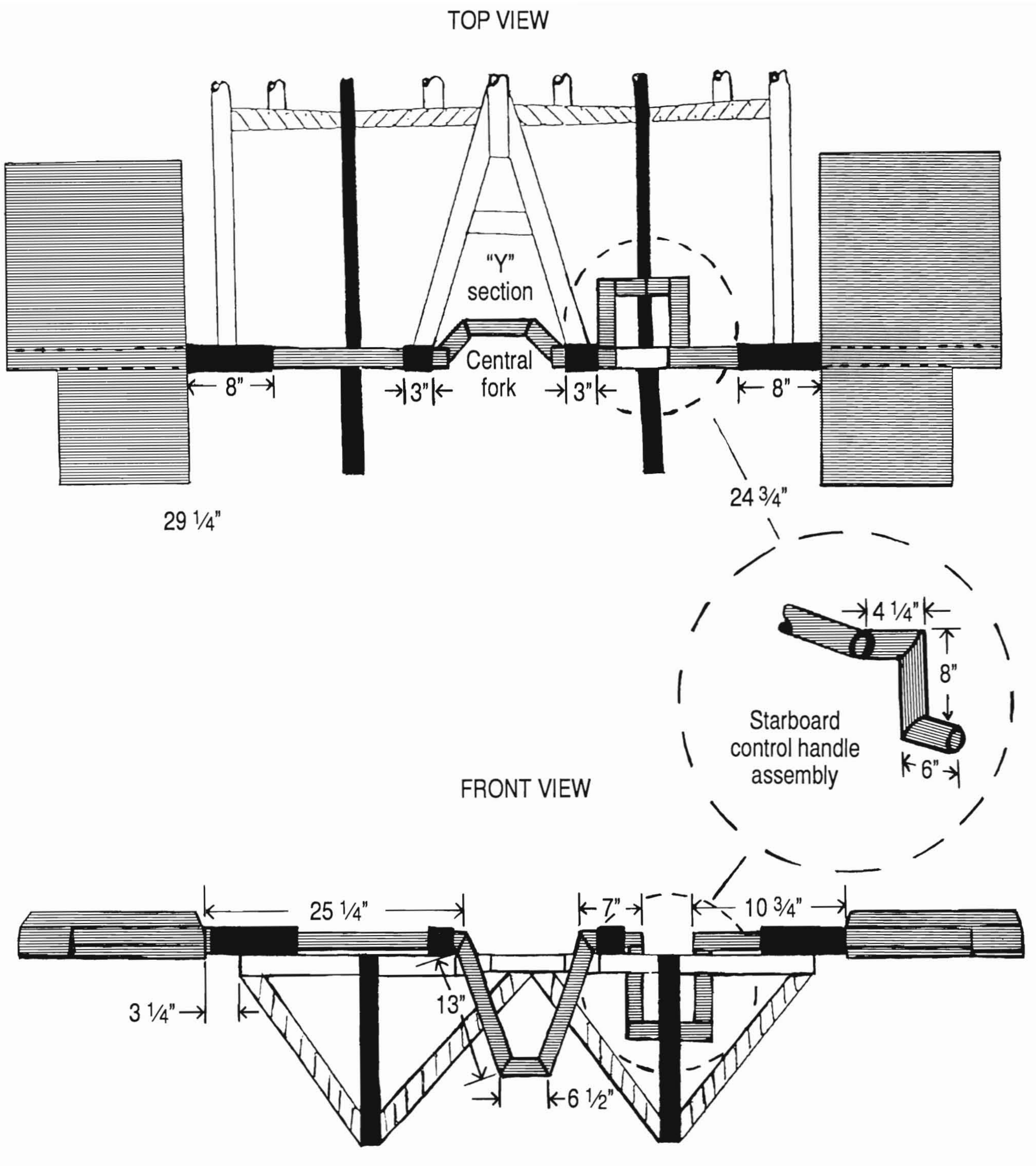


Figure 6.—Sled dive controls.

diesel engines. The only limiting factor is speed. Safe operating speed ranges from about 0.5 to 4 knots.

Selection of the size of the sled towline is dependent upon line type, towing speed, and the towing vessel's handling capabilities. For a nylon towline, the size ranges from ⅜ to ¾ inches. Warp (the amount of towline) depends on the depth

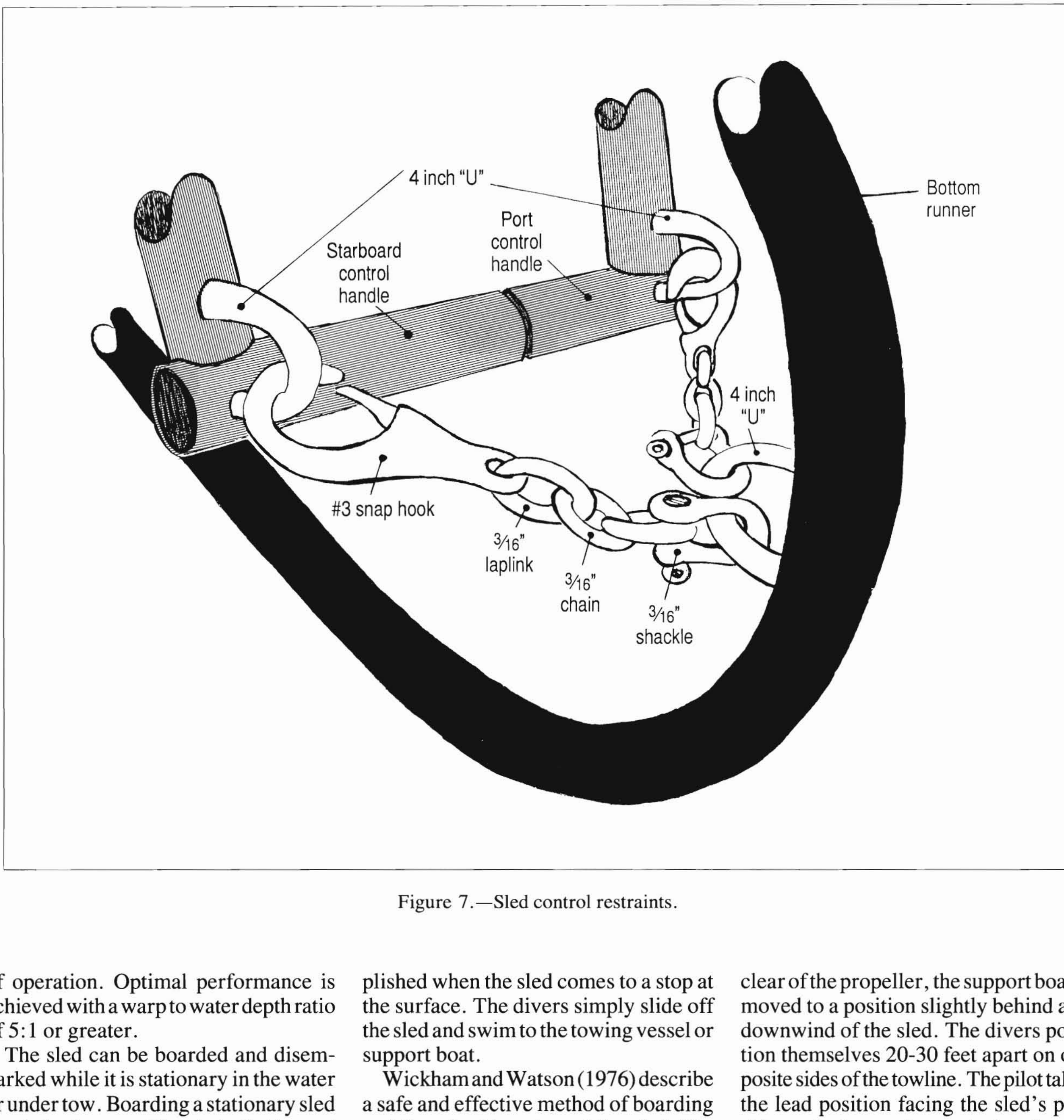


Figure 7.—Sled control restraints.

of operation. Optimal performance is achieved with a warp to water depth ratio of 5:1 or greater.

The sled can be boarded and disembarked while it is stationary in the water or under tow. Boarding a stationary sled is relatively easy. The sled pilot to port and observer to starboard slide on, either singly or together, from the sides or the stern, and assume a prone position. A third diver, when needed, would take a central position between the pilot and observer. As the sled is boarded it will sink, and care must be taken to avoid capsizing. Towing can begin when the divers are ready. Disembarking is accomplished when the sled comes to a stop at the surface. The divers simply slide off the sled and swim to the towing vessel or support boat.

Wickham and Watson (1976) describe a safe and effective method of boarding and disembarking a towed dive sled. The divers, transported in a support boat (separate from the towing vessel), are positioned well ahead of the sled and close to the downwind side of the sled towrope. When the divers are ready to enter the water, the support boat is turned away from the towrope, and the motor is taken out of gear.

Once the divers are in the water and clear of the propeller, the support boat is moved to a position slightly behind and downwind of the sled. The divers position themselves 20-30 feet apart on opposite sides of the towline. The pilot takes the lead position facing the sled's port side, grabs the passing control surface or sled frame, and trails back to a parallel position. The pilot then slides aboard the sled and assumes a prone position at the controls. The observer boards the sled in the same manner from the opposite side.

When the divers are positioned, the pilot releases the control restraints and assumes control of the sled. At the end of the dive, the sled is brought back to the surface and the control restraints are reattached. The support boat is then signaled in to a parallel position close to the downwind side of the sled. On the pilot's signal, the support boat's motor is taken out of gear, and the divers kick free of the sled and swim to the support boat.

## Piloting the Sled

The sled pilot must be experienced in the handling characteristics of the sled and familiar with the requirements of each diving operation. During a dive, the pilot must maintain open communications with the passenger(s) and be aware of any changes in depth. Depth changes without adequate time for the divers to equalize pressure in internal air spaces could result in barotrauma, air embolism, or other related problems. An accelerated ascent rate faster than 18.3 m/minute (60 feet/minute) following a long or deep dive could result in decompression sickness. The following are basic flight control instructions.

### Descent

Both control handles are pulled back toward the pilot. The rate of descent is dependent upon towing speed and the distance the control handles are pulled back.

### Ascent

Both controls are pushed forward away from the pilot. Ascent rate is dependent upon towing speed and the distance the control handles are pushed forward.

### Level Flight

Once working depth is reached, the pilot places the control handles at their approximate midpoint. To maintain level flight, slight back and forth adjustments might be necessary.

### Flying to Starboard

After submerging (descent), the pilot pulls the port control handle back and holds the starboard control at its midpoint or pushes it slightly forward. When the desired angle of attack is reached, the pilot pulls the starboard control back. Slight adjustments in the controls might be required to maintain the angle of attack. For side flight without depth change, the sled must be turned and held perpendicular to the bottom.

### Flying to Port

Opposite of flying to starboard.

### Barrel Roll

At times it may be necessary to completely roll the sled. To do this, the sled must be submerged to a depth (dependent upon speed) that it will not break the surface as it rolls. One control handle (port or starboard) is pulled all the way back while the other is pushed all the way forward.

## Safety Notes

Safety should be stressed at all times in the use of a diving sled and in the overall operation of its towing vessel and support boat. Adequate diving instruction as outlined in the NOAA Diving Manual (Miller, 1979) should be obtained before receiving sled operation instructions, and all sled users should receive classroom and practical in the field instruction before attempting to use a diver's sled.

Communication is a primary safety factor in using a diver's sled. Although voice communication is possible with proper underwater communication equipment, it is not always practical, depending on the type of diving operations conducted. It is therefore most important that the sled pilot and observer(s) learn a simple set of hand signals (depicted in the NOAA Diving Manual) before attempting a sled dive. The center for communications is the pilot who has overall control of the dive. It is the pilot's responsibility to insure that all sled flight changes (e.g., descending, ascending, etc.) are communicated and clearly understood by the observer(s) before they are initiated. The observer can initiate communications with a light tap or squeeze on the pilot's arm.

All sled users should have a working knowledge of Boyle's Law and understand the possible problems involved with pressure-volume changes (e.g., barotrauma, air embolism, and other related problems). Particular attention should be paid to breathing rhythm. On descent and level flight, breathing should be regular. When ascending, the breathing rhythm should be modified to shortened inhalations followed by long exhalations to prevent lung over-pressurization.

## Acknowledgments

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