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REPORT ON FISH AGGREGATING DEVICES WORKSHOP

By

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I. INTRODUCTION

An informal workshop on fish aggregating devices (FAD) was held on October 23, 1980 at the National Marine Fisheries Service (NMFS), Honolulu Laboratory. The purpose of the workshop was to discuss the mounting problem of FAD losses.

The agenda agreed upon was to describe in detail the construction of mooring lines of the various FAD presently in use, to identify the causes of mooring line failures, and to determine the changes necessary in reducing FAD losses. The discussions were followed by presentation of catch results to date around the Hawaii statewide FAD system and of the ecological build-up of fish populations around the FAD.

II. GEAR CONSTRUCTION AND LOSSES

A. NMFS Experimental FAD

The NMFS used two types of mooring configurations. The first type (Figure 1a) consisted of a 50-ft length of chain attached to the buoy with a 5/8-in. galvanized shackle. The lower end of the chain was shackled to a 5/8-in. galvanized swivel and, in turn, to the 5/8-in. polypropylene rope. The lower end of the rope was attached to the anchor chain in a similar manner with a swivel and shackles. An intermediate weight of large chain links was connected to the rope section by a loop of either 5/16- or 3/8-in. chain with comparable sized shackles. The lower end of the intermediate weight was also fitted with a galvanized swivel. All rope ends were spliced to about 14 in. around heavy-duty cable thimbles. Sections of rope coils were joined together by long splices in which about 1 fathom of line was twisted around each other and each end spliced into the opposite line for a length of about 15 in. All splices, including that around thimbles, were seized with nylon twine at two places. All shackle pins were secured with galvanized wire.

The second type (Figure 1b) was constructed in a similar fashion, except that the 50-ft chain length at the buoy end was replaced with a 100-ft length of 3/8-in. galvanized wire rope. Both ends of the wire rope were fitted with 3/8-in. heavy duty thimbles and fastened with three safety wire grips.

The original set of four devices off Oahu and Lanai included a short section of 3/8-in. wire rope, fitted with floats, which was attached to the mooring line between the rope and anchor chain. Because copper nico-press sleeves were used to fasten the thimbles at both ends of the wire rope, this part of the line failed after about 2 months due to electrolysis. This section was omitted from later buoys because the buoyance of the polypropylene rope was sufficient to keep the line off the bottom.

During the remainder of the experiment, six more devices were lost at the four sites. Three from undetermined causes after 4, 17, and 20 months, two from causes other than mooring line design failure (one by rope chafing on bottom ledge, the other after having been dragged by currents to shallower waters where line chafing presumably occurred at the intermediate weight), and one due to loss of shackle pin. Only two of the six lost buoys were recovered.

Off Kona, four devices were lost at two sites. The initial two devices made of wooden rafts were lost as the rafts broke apart during a storm with winds in excess of 80 knots. The two replacement buoys, made of 55-gal drums, were moored by lines consisting of 100 ft of 3/8-in. wire rope at the top in place of the chain section, were also lost; one from undetermined causes, the other, as the cable grips became loose.

B. American Samoa FAD

The FAD used in American Samoa consisted of buoys made of three 55-gal drums filled with foam. The NMFS designed mooring configuration differed slightly from that used in Hawaii. Two types of lines were designed for shallow and deep moorings. The single shallow mooring (Figure 2a) consisted of a 10-ft length of 1/2-in. chain shackled to a padeye on the buoy. A galvanized swivel was shackled to the chain section and to a length of 3/8-in. wire rope. A 150-ft length of chain was shackled to the anchor and the wire rope. Each end of the wire rope was secured around a thimble with three safety wire grips and coated with fiberglass. All shackle pins were secured with galvanized wire.

The nine deep moorings design (Figure 2b) consisted of 10 ft of chain, followed by 100 ft of wire rope and 5/8-in. polypropylene rope. The rope end was attached to a 30-ft long anchor chain. An intermediate weight of large chain links was shackled into the rope section. Galvanized swivels were placed at the lower end of the intermediate chain weight and at the lower end of the rope. All connections were made with 5/8-in. galvanized shackles and the shackle pins were secured with galvanized wire and fiberglassed.

After learning about slippage in the safety wire grips in the Hawaiian experiment, the wire rope section was altered so that it was removed from some of the deep moorings and added on to others (doubled up). Thus, five buoys were set without the wire rope section, two were set with double wire rope section, and two were set with single wire rope section. The wire rope on the shallow mooring was also doubled up.

Of the 10 devices moored in October 1979, 6 were either lost or reported missing to date. Of the four remaining buoys, three had no wire rope section and one (shallow mooring) had double wire ropes. Of the buoys that broke free, one did so as a result of being overrun by a tugboat. The other confirmed breakage occurred at the rope section beneath the wire rope at the end of the splice. It was believed that the absence of a swivel at the junction of the wire rope and the rope section was the cause of line failure. The broken end of the rope showed signs of having been twisted.

C. Eastern Pacific FAD

The Inter-American Tropical Tuna Commission moored three FAD from August 26 to September 22, 1980 in the eastern Pacific between lat. 10°N and 15°N, 390 to 630 mi offshore in depths of 1,600 to 2,200 fathoms. A description of the devices and mooring line construction was presented as an alternative to the systems presently in use.

The device was a 4 ft x 12 ft x 8 in. raft made of plyboard and filled with foam. The mooring consisted of a swivel, attached to a cross-piece on the raft, followed by 20 fathoms of 1/2-in. wire rope and the rope section. The ends of the wire rope were spliced around thimbles. The rope section consisted mostly of 5/8-in. polypropylene rope in the upper section, with the lower sections of 3/4-in. and 7/8-in. rope. One-inch galvanized swivels were inserted between rope coils and the ends of the rope were knotted to the swivel eyes. At the lower end, the rope end was knotted around four tire sidewalls. Three 1-in. polypropylene rope bridles led from the four tire sidewalls to two tire sidewalls imbedded in concrete in each of three 55-gal. drums. The mooring line had a scope of nearly 1:1.

Although the FAD have not been in place long enough to prove their durability, one of them has withstood a hurricane with winds of up to 105 knots. Because the raft is constructed of lumber, it is expected that the raft will break up in due time. The lack of any ballast on the raft will make it prone to capsizing, and one raft has already done so.

D. Palau FAD

The Palau FAD (Figure 3) was patterned after that of the Hawaii State system (see below), but with some changes. The ballast and mast were made of a single length of 4-in. pipe which projected 8 ft below and 6 ft above the buoy. The attachment for the mooring line was a single L-shaped steel plate bolted onto the underside of the buoy.

The mooring line consisted of a 20-ft long 1/2-in. chain which was looped through a hole in the attachment and shackled. The lower end of the chain was shackled to a 3/4-in. galvanized swivel and, in turn, to the main section of 5/8-in. polypropylene rope fitted with a galvanized thimble. The lower end of the rope section was shackled to a swivel and 50-ft of 1/2-in. chain which was shackled onto a 1,000-lb marine anchor. An intermediate weight of large chain links was shackled onto the line with a galvanized swivel attached at the lower end. The rope sections were connected to each other by long double splices and three or four swivels were spaced along the length of the rope section. All shackle pins were secured with galvanized wire.

Six FAD were moored in late July and early August, 1980 in depths of 600 to 2,022 fathoms, all with line scope of 1.6:1. To date, one FAD has broken loose. The cause of line failure has not been determined, but because the FAD were anchored in areas with numerous high steep ridges, there was a possibility that the line may have chafed against the ridges.

E. Guam FAD

The Guam FAD, initially, were made of three 55-gal drums filled with foam and with four leg supports to the ballast pipe (Figure 4). Chain bridles attached to the middle of the buoy were linked to 75 ft of chain with shackles and a swivel. The remainder of the mooring line was similar to that of the NMFS line, but the anchor was made of T-shaped concrete block.

Two devices were anchored in 300 and 510 fathoms in December 1979 and January 1980. Due to insufficient intermediate weight, the excess rope floated to the surface. The first device broke free within 1 week and was subsequently retrieved. It was believed that the floating line was severed by the propellor of a fishing boat. Additional weight was added to the mooring line of the second buoy as a corrective measure. This device also broke free in May. It was assumed that the break had occurred either at the intermediate weight or at a splice.

On the replacement FAD, the design was altered to a tire platform type and the rope size was increased to 3/4 in. Additional padeyes were placed on the buoy to permit small boats to tie up to it.

One of the two buoys deployed in April and June broke free recently. The break had occurred at the junction between the bridle and the upper chain section. The shackle was missing.

F. Marianas FAD

The Marianas FAD was made of three drum buoys with the mooring line attached to the end of the ballast pipe. The mooring line (Figure 5) consisted of 50-ft lengths of chain at the buoy and anchor, with a main section of 5/8-in. polypropylene rope, that contained an intermediate weight. Swivels were shackled onto the ends of the chain sections, including both ends of the intermediate weight, and another in the rope section below the intermediate weight. A concrete block weighing 3 tons was used as the anchor.

Of five FAD anchored during February-March 1980, all have been lost. The FAD had been deployed without the aid of radar or depth recorder; consequently, one device was set too deep and disappeared from sight, two others were set too shallow and were probably lost as a result of the line chafing on the bottom at the intermediate weights. Two others showed signs of having been run over by passing vessels prior to their disappearance.

G. Hawaii Fish and Game FAD

The Hawaii Fish and Game FAD (Figure 6) were constructed of 6-ft diameter, 22-in. wide rubber tire, enclosed by steel plates over the open sides and fitted with polyurethane foam. A mast of pipe and PVC (polyvinyl chloride) pipe extension was attached to the top plate. The mast extension contained a battery pack topped with a flashing light. Vertical steel gussets welded to the top plate served to support the mast. An 8-in. pipe, 8 ft long, filled with 350 lb of scrap iron was welded to the bottom plate and served as ballast.

The mooring line configuration is shown in Figure 7. The top of the bridle was shackled to two padeyes through a split chain connecting link. The lower end of the bridle was connected to a bronze swivel by split chain connecting links and the swivel was shackled to 100 ft of 1/2-in. chain. The lower end of the chain was attached to a swivel through a split chain link, and the swivel was shackled to the rope end fitted with a 3/4-in. Newco bronze thimble. Similar linkages were made below the intermediate chain weight and at the anchor chain. The top of the intermediate chain weight was linked without any swivel.

The FAD was moored to a 3,000-lb Baldt- or Danforth-type anchor to which 30 ft of 1/2-in. chain was attached with a 3/4-in. shackle and split chain link. The body of the mooring line consisted of 3/4-in. polypropylene medium-lay rope. The rope sections were connected to each other by a single splice consisting of about 10 tucks.

Twenty-six FAD were moored around the main Hawaiian Islands between May and July between May and July 1980 in depths ranging from 250 to 1,200 fathoms. To date seven FAD have broken loose, three of which were recovered. One of the breaks was due to a tugboat towline. The second was probably due to splice failure, either at a thimble or between rope sections. The latter showed signs of electrolysis at the bronze swivel after 5 months; however, bronze thimbles showed little, if any, corrosion. The causes of failure of the other five FAD were undetermined.

III. IDENTIFYING PROBLEM AREAS

Of the 33 reported losses to date, 17 definite and 4 probable failures were identified. Twelve causes of failures were not determined, since the buoys were not recovered. The number of definite and probable failures are tabulated below:

	Failure	Definite	Probable	Total	Cause
1.	Shackle	2		2	Fabrication
2.	Rope splice	1	1	2	Fabrication
3.	Cable grip	1	2	3	Fabrication/design
4.	Nico-press sleeve	4		4	Design
5.	Rope twist	1		1	Design
6.	Rope cut by propeller	1		1	Design
7.	Rope chafing	4	1	5	Setting error/ design
8.	Buoy set too deep	1		1	Setting error
9.	Run over by tugboat	2		2	Accidental/design
		17	4	21	

Remarks on Itemized Failures

1. Shackle failure usually occurred as a result of the pin working itself loose. This can be delayed to some extent by securing the pin with galvanized wire, but there is always the possibility that the wire used could be too small and corrode within a short time, or that some of the shackles could be overlooked and not be secured at all. Mr. Ian Blogg, who has had wide experience with long-term deep moorings, noted also that he has observed shackles with the pin completely corroded.

2. Poor splicing, particularly single, short splices, and splices that are loose, could be pulled free. This is especially so when using slippery synthetic ropes made of such materials as polypropylene and nylon.

3. Cable grip failure was probably due to insufficient or uneven tightening of the two bolts. The buoys, in this case, were not out long enough for corrosion to set in, but the small bolts on the grip could corrode in due time.

4. The nico-press sleeve failure resulted from electrolysis caused by using copper sleeves on galvanized steel wire rope. The failure occurred during the initial experimental stage in the development of the buoys.

5. Rope twist caused by the absence of a swivel between the top chain section and the rope section resulted in a break in the rope adjacent to the splice. The twist was imparted either by buoy rotation or rotation of the rope, or both.

6. The severing of the mooring line by a boat's propeller resulted from failure to attach sufficient weight to the rope. This allowed the excess line to float to the surface, where it was overrun by a boat.

7. Rope chafing was largely due to misplacement of the buoys. The buoys were placed too close to bottom ledges or anchored in depths much shallower than intended. In the latter case, chafing is believed to have occurred when the intermediate weight reached the bottom. Rope chafing can also occur when the currents are strong enough to drag the buoy anchor. One buoy was dragged into waters shallower than the intermediate weight and was eventually lost.

8. This buoy was set in waters deeper than intended due to lack of proper instrumentation, i.e., depth recorder and navigational instruments.

9. The rope section of the mooring lines of two buoys were severed by tugboat towline. In one instance the tugboat approached too close to a buoy out of curiosity; in another incident the tugboat, most likely, failed to notice the buoy.

IV. CORRECTIVE MEASURES

Most of the failures can be considered as one time occurrences. Failures stemming from the use of cable grips and copper sleeves on steel wire rope need not reoccur if these items are not used in future fabrication. Incidences of rope being severed by propellers also need not occur if all are aware of the buoyancy of polypropylene rope and adjust it with an intermediate weight. Setting the buoys too shallow, resulting in rope chafing, and setting them too deep, resulting in complete submergence, need not occur if the buoys are set with the aid of proper navigational and depth-sounding equipment.

Other failures involving shackles, rope splices, and rope twists are more serious, since they can occur in future moorings. These require extreme care in fabrication. Shackle failures can be reduced if the pins are secured and coated with epoxy or fiberglass resin. The epoxy and resin will inhibit corrosion and also freeze the pin and prevent it from working itself loose. An alternative would be to replace all shackles with over-sized split chain links. This too should be coated with epoxy or resin.

Because of the numerous rope splices required to construct a deep mooring line, it is imperative that the splices are securely made. This is especially critical with synthetic rope since this type of rope are prone to slip. For added security, the rope ends should be double-spliced, with each splice made at least 15 to 18 in. long and seized with twine at two or three places.

Line breaks due to twisting can be avoided by the addition of sufficient number of swivels at critical places. These are at the ends of the top and bottom chain sections and at the lower end of the intermediate weight. Additional swivels may be added to the top of the intermediate weight and midway on the rope below the intermediate weight.

The swivels presently used, chain-link type, were suggested as being of inferior quality. Galvanized, barrel-type swivels with bearings were considered better since they were free to turn under heavy load.

One other problem that needed consideration was the avoidance of electrolysis which occurs when fittings made of different metals are placed next to each other. All fittings, thus, should be of uniform metals.

Mr. Blogg presented his ideas on ideal moorings. For moorings in excess of 500 m, he preferred a round buoy (Figure 8) with a line scope of 1:1, with bearing race swivels at the buoy, top and bottom of rope section. Because strain on the mooring line was concentrated in the upper 100 ft, the first section to approximately 20 fathoms should be of chain. For shallower moorings, he suggested an all chain tether consisting of a heavier chain section at the bottom attached to a dome-shaped anchor, the last to prevent the chain from winding around it. To overcome the weight problem, part of the mooring line could be of wire rope jacketed with a coating of epoxy. Epoxy fitted sockets and swivels were to be used at the ends of the wire rope. Such a mooring could withstand a current force of up to 4 knots.

V. CATCH RESULTS AROUND HAWAII FISH AND GAME FAD

Mr. Robert Nishimoto presented the catch results of the Hawaii statewide buoy system. To obtain catch data, the Hawaii Fish and Game distributed 5,000 postpaid cards. They obtained a response of about 3%.

The reported catch from April through mid-September 1980 was 237,300 lb. The breakdown of catches by major islands were: Kauai, 18,800 lb; Oahu, 168,300 lb; Maui-Molokai-Lanai, 31,704 lb; and Hawaii, 18,500 lb. Eighty-five to ninety-three percent of the catch at all the islands consisted of skipjack tuna. Other species taken around the buoys were yellowfin tuna, bigeye tuna, kawakawa, mahimahi, ono, striped marlin, blue marlin, and spearfish.

VI. BIOLOGICAL ASSESSMENT OF THE HAWAII FISH AND GAME FAD

Dr. Richard Brock presented preliminary results of his study on colonization and biomass build-up around the Hawaii buoys. Monitoring a newly redeployed buoy for a period of 36 days provided data on the colonization process. Juveniles of oceanic driftfishes, <u>Psenes cyanophrys</u>, began recruiting to the buoy within 15 minutes. The number of species increased rapidly to about ten in 15 to 20 days and remained steady through the 36th day. The data also showed that there was a turnover of fish species at the buoys and that a turnover rate (the number of fish species leaving or disappearing from the buoy area divided by the return or recruitment of new species) of 1.0 was attained in 20 days. This turnover was found to occur in about half of the fish species present around the buoy. The driftfish; large filefish, Alutera scripta; kahala, Seriola dumerili; yellow papio, Gnathanodon speciosus; opelu, Decapterus macarellus; and mahimahi were all regular buoy residents.

Dr. Brock also reported that the standing crop of fishes, observed over this period at U buoy, was found to increase exponentially over time. One buoy deployed for more than 180 days had a standing crop of yellowfin tuna estimated at 1,600 metric tons. The yellowfin tuna school, consisting of large fish, 55 to 70 kg in weight, engaged in feeding activity at the surface in the morning and at dusk, and spent the remainder of the day as a nonfeeding school 80 to 200 m beneath the buoy.

Other observations at the buoys indicated that (a) schools of opelu were usually found above the yellowfin tuna school, (b) small forage fish near the buoys were generally wiped out by large tunas feeding on them, (c) there were many shoreside fish build-up around the buoys, but they lasted only for short periods before being preyed upon, and (d) the arrival of boats to the buoys caused the fish groups to sound.

VII. PARTICIPANTS

Ian Blogg	ALA-PAC, Seattle, Washington
Richard E. Brock	Hawaii Institute of Marine Biology, Honolulu, Hawaii
Patrick Bryan	Office of Marine Resources, American Samoa
Doyle E. Gates	Western Pacific Program Office, Southwest Region (SWR), Honolulu, Hawaii
Mike Gawel	East-West Center, Honolulu, Hawaii
Richard M. Howell	Guam Fishermen's Cooperative Assn., Agana, Guam
Gerson Jackson	Marine Resources Division, Kosrae, Micronesia
Alvin Katekaru	Hawaii Division of Fish and Game, Honolulu, Hawaii
Joseph Matanane	Government of Guam, Agana, Guam
David Nada	Pacific Tuna Development Foundation, Honolulu, Hawaii
John J. Naughton	Western Pacific Program Office, SWR, Honolulu, Hawaii
Robert T. Nishimoto	Hawaii Division of Fish and Game, Honolulu, Hawaii
Eugene Nitta	Western Pacific Program Office, SWR, Honolulu, Hawaii
Toshiro Paulis	Trust Territory Marine Resources Division, Saipan, Northern Marianas
Doug Souter	Living Marine Resources, San Diego, California
Joaquin P. Villagomez	Marine Resources Development Division, Saipan, Northern Marianas

Convenor

Richard S. Shomura	Honolulu Laboratory, Southwest Fisheries Center, NMFS, Honolulu, Hawaii

Rapporteur

Walter M. Matsumoto	Do.

Figure 1. NMFS mooring line configuration.

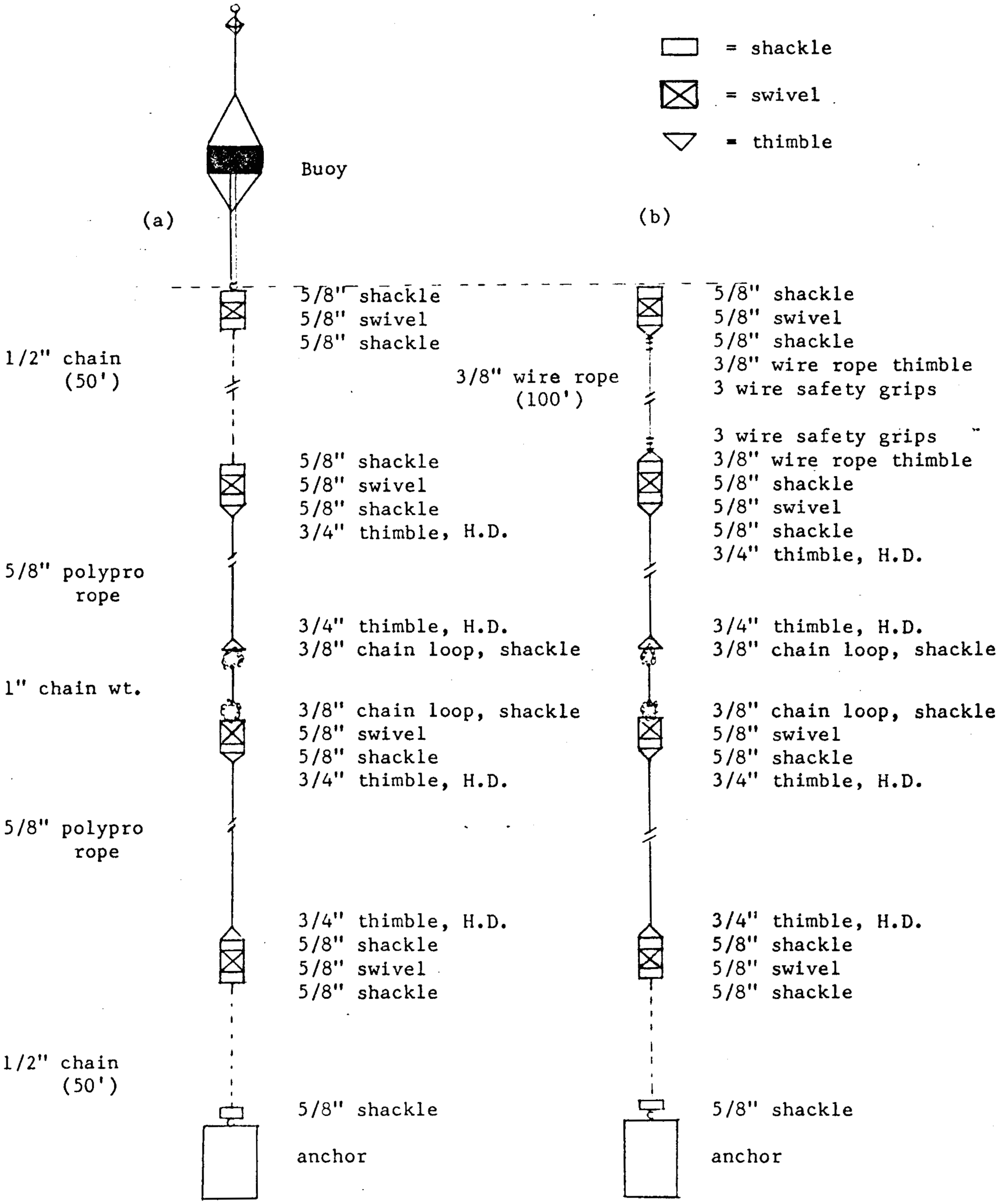


Figure 2. American Samoa mooring line configuration.

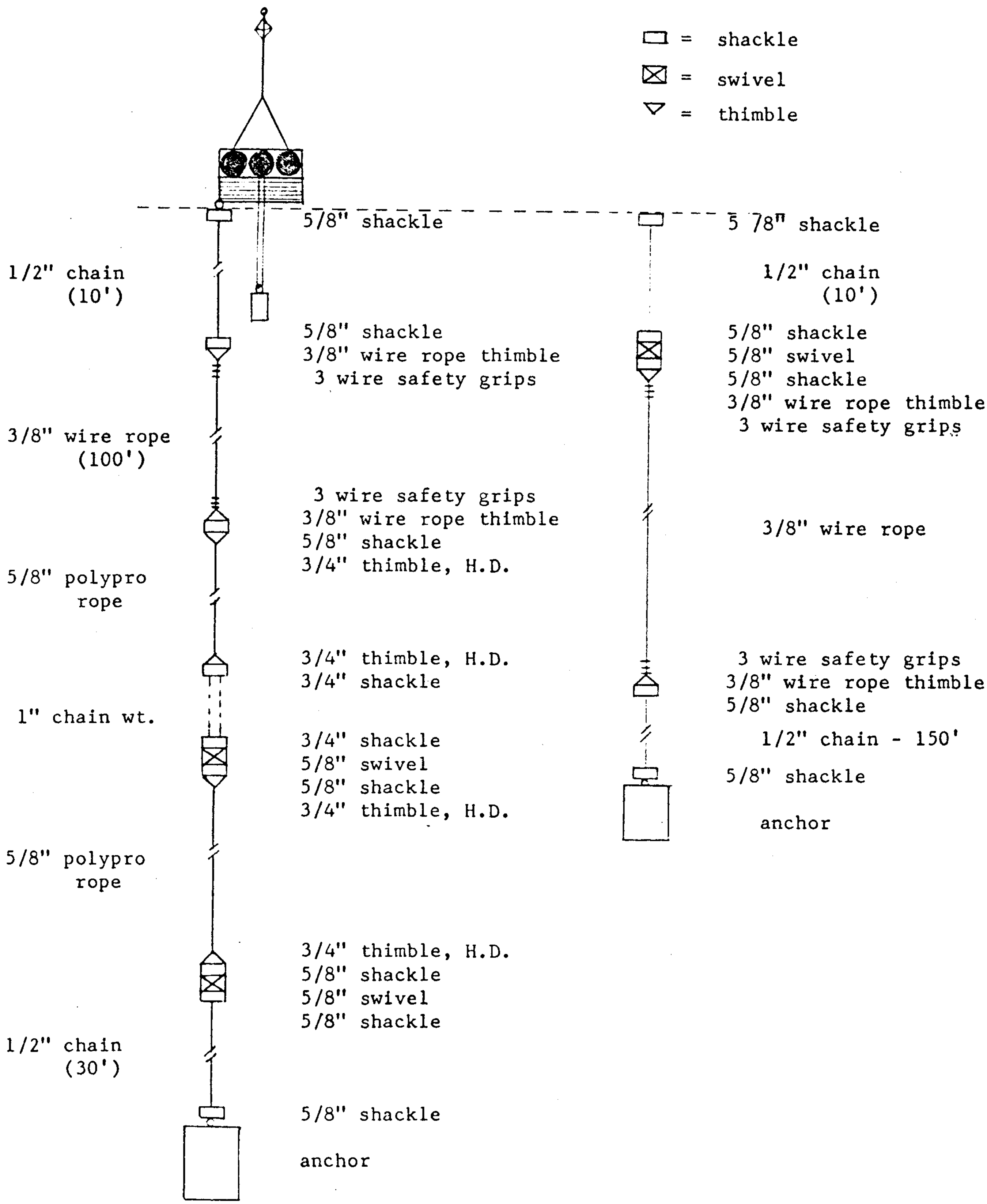


Figure 3. Palau FAD and mooring configuration.

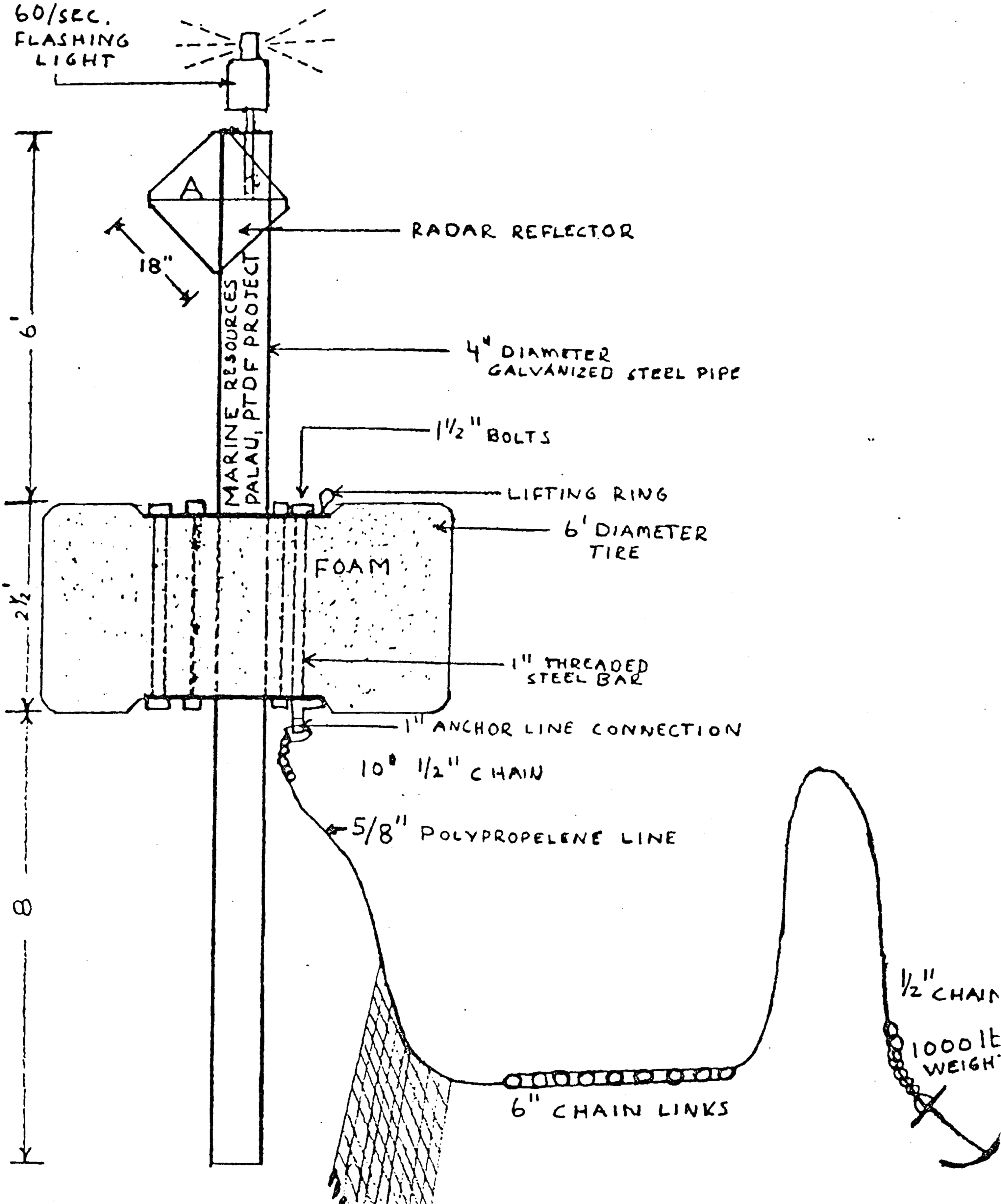


Figure 4. Guam FAD and mooring configuration.

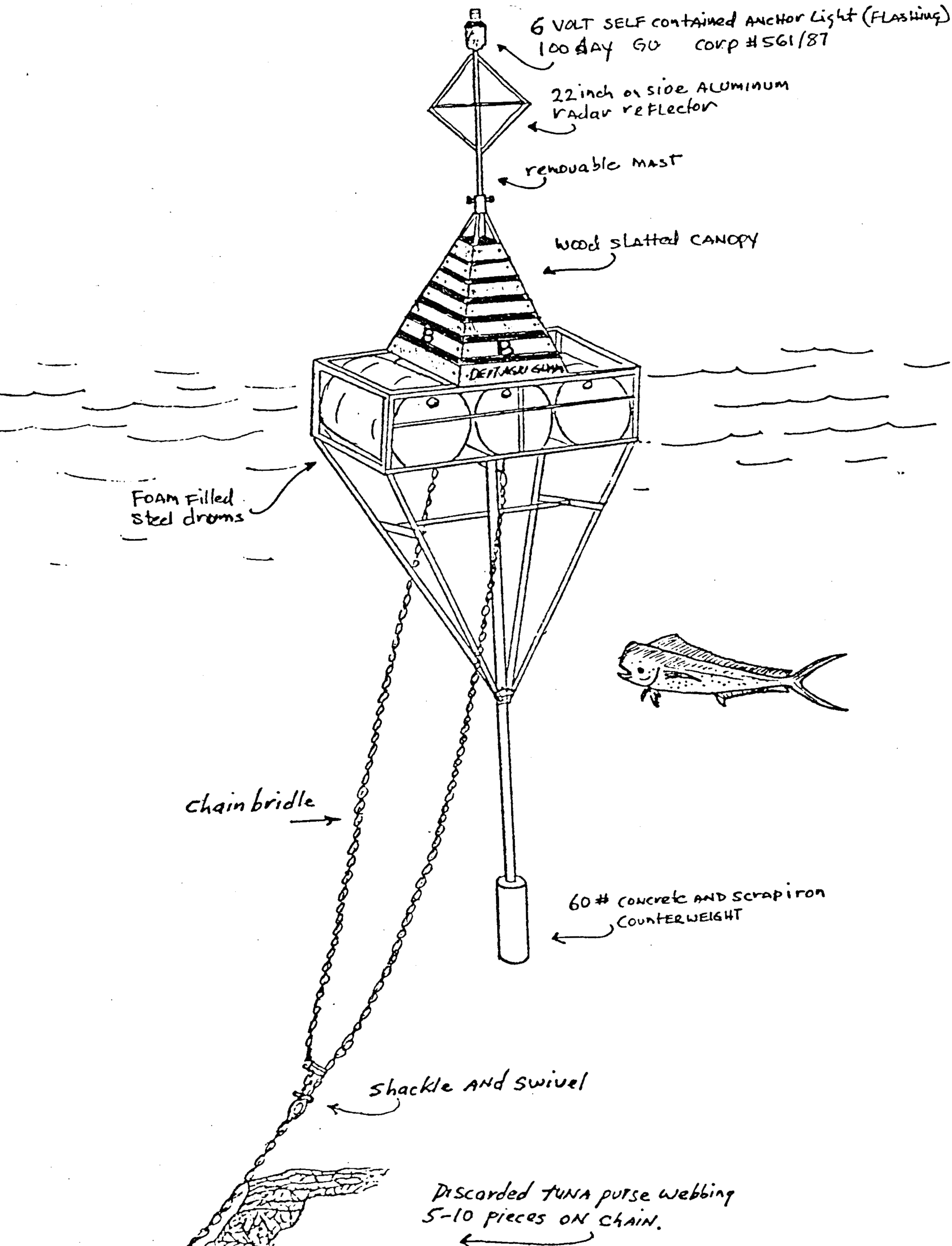


Figure 5. Marianas FAD mooring configuration.

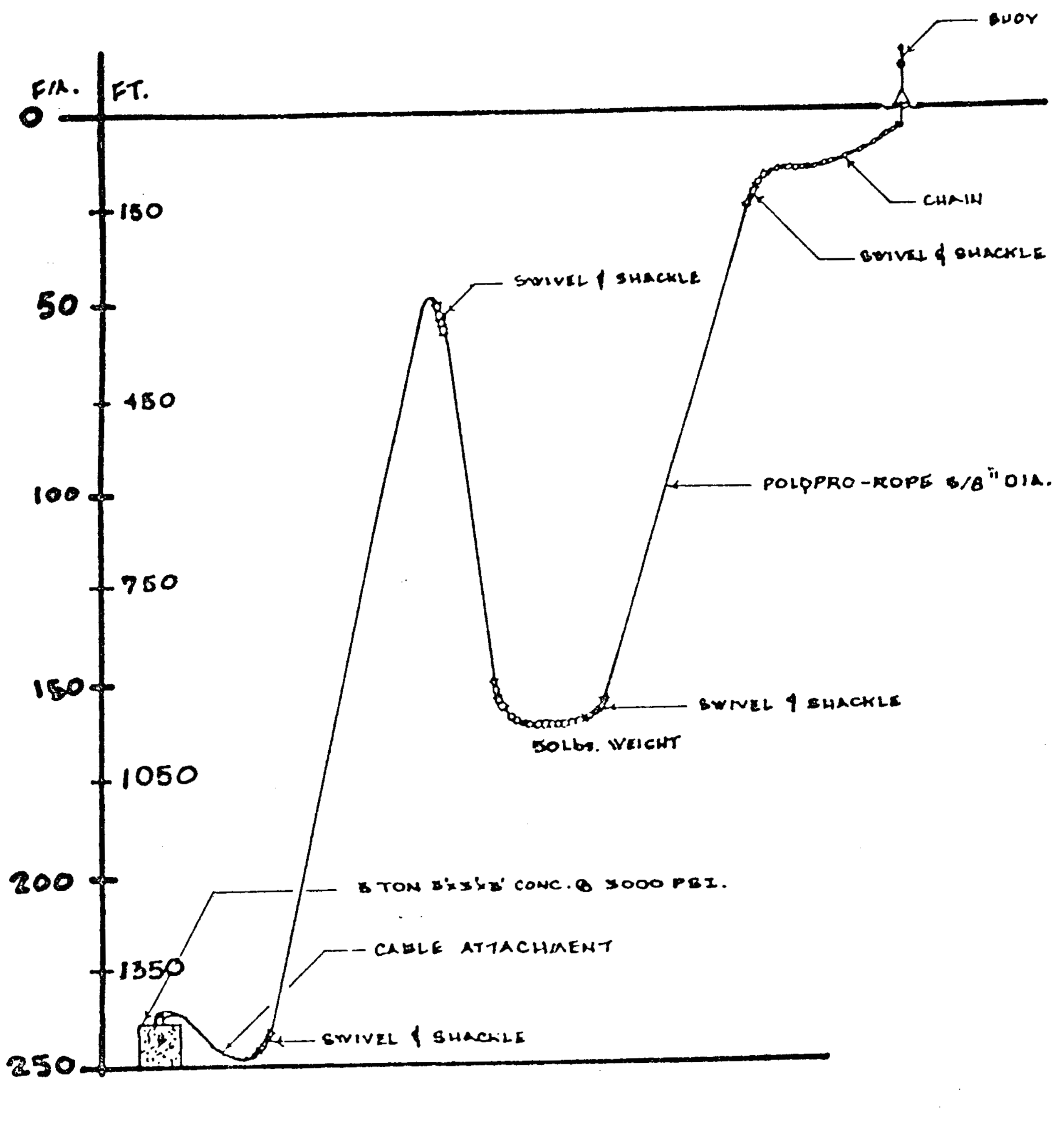


Figure 6. Hawaii Fish and Game FAD.

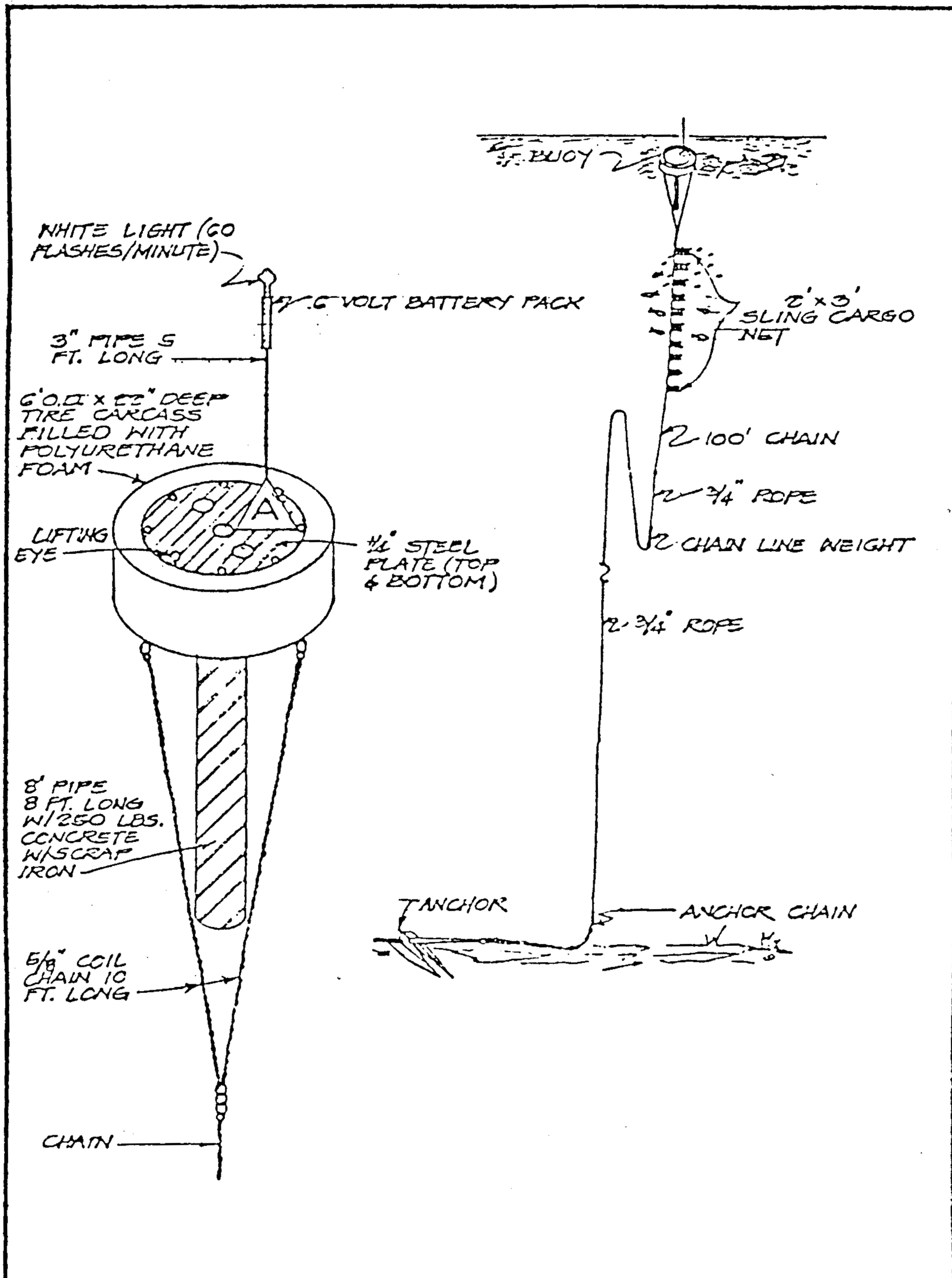


Figure 7. Hawaii Fish and Game mooring details.

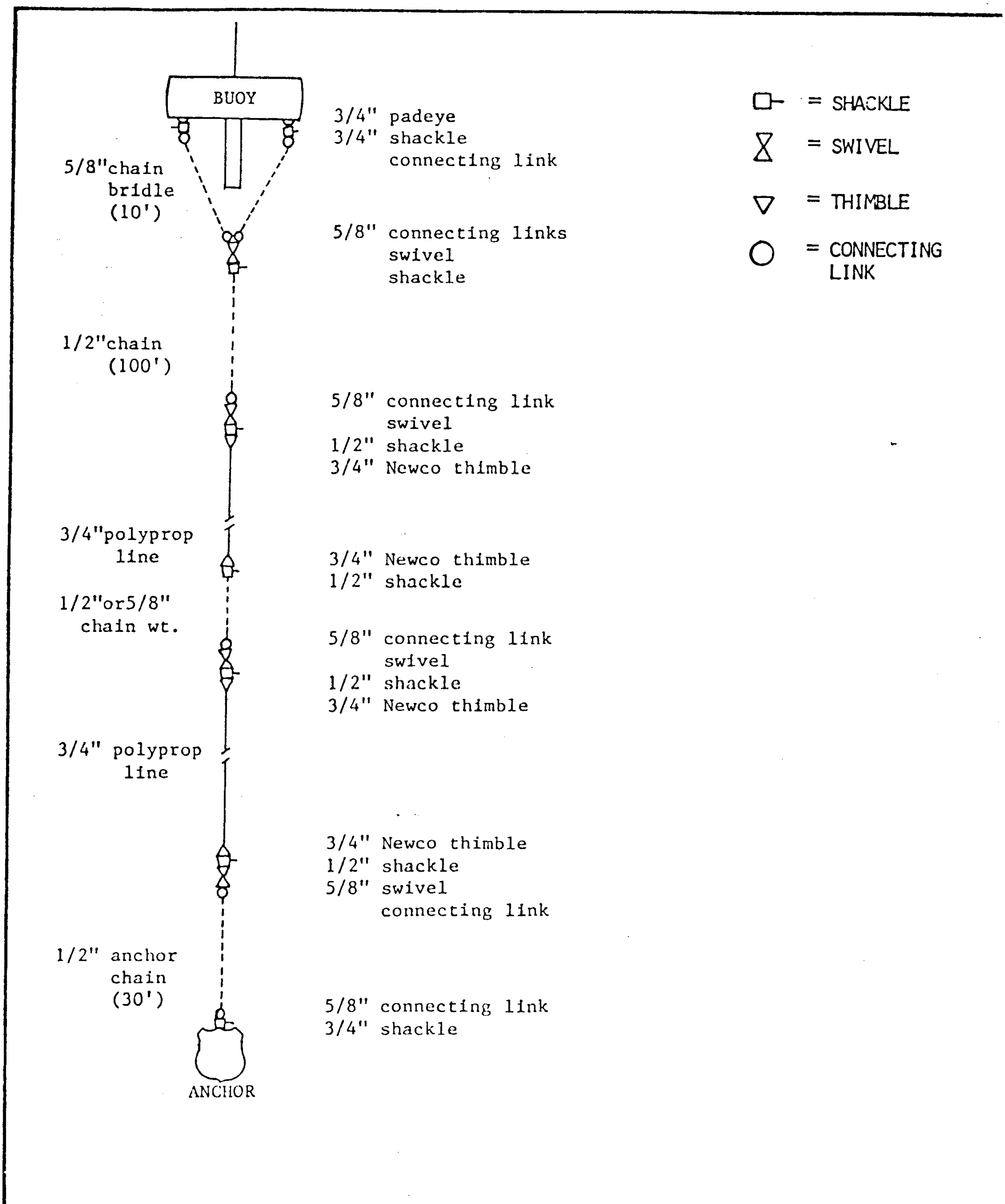
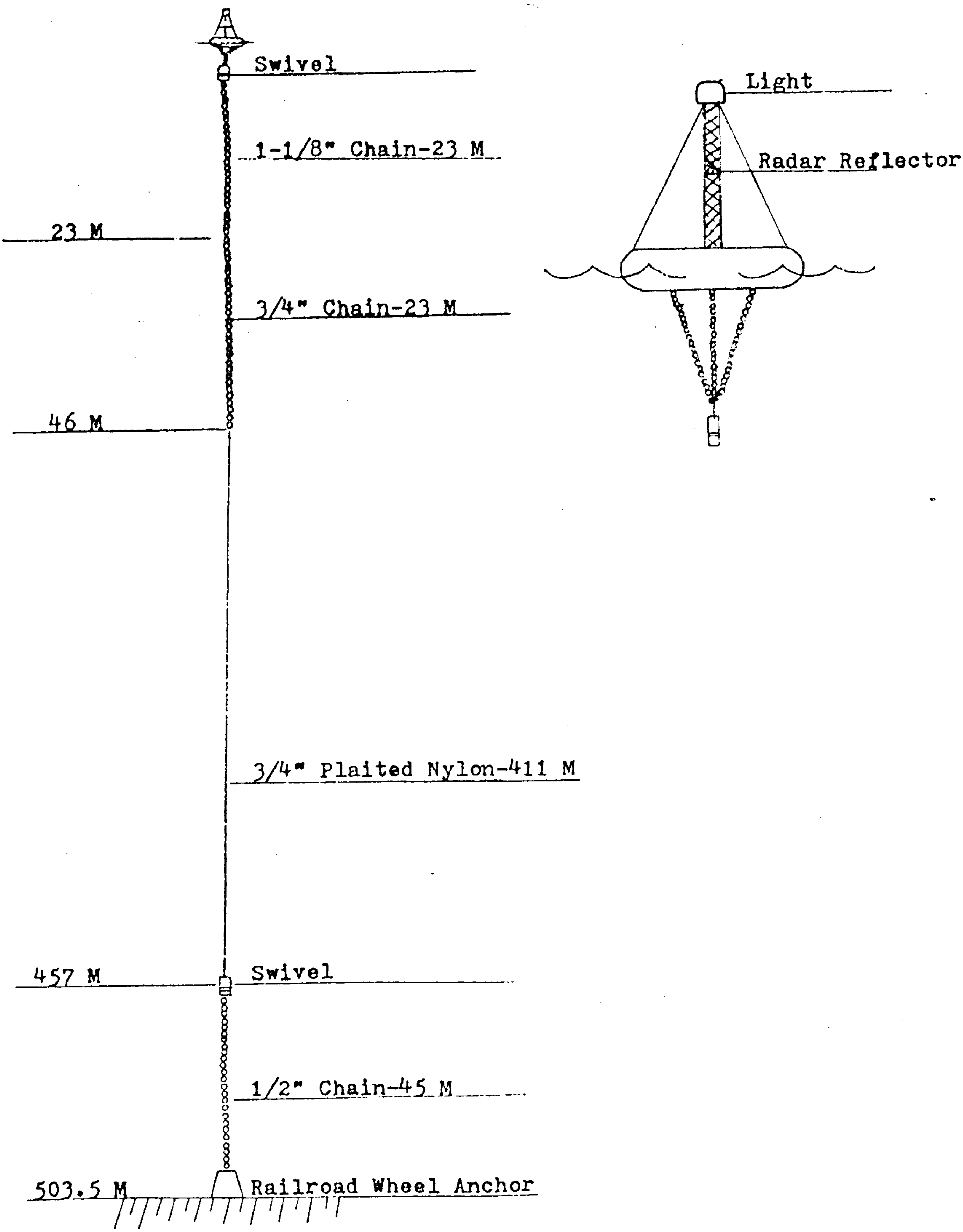


Figure 8. Suggested ideal mooring.



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1.	Mr. Ian Blogg	9407 E. Marginal Ways, Seattle, WA 98108
2.	Dr. Richard E. Brock	Hawaii Institute of Marine Biology, UH, P. O. Box 1346 Kaneohe, HI 96744
3.	Mr. Patrick Bryan	Office of Marine Resources, Government of A.S. P.O. Box 6 Pago Pago, American Samoa 96799
4.	Mr. Doyle E. Gates	Western Pacific Program Office, Southwest Region, P. O. Box 3830, Honolulu, HI 96812
5.	Mr. Mike Gawel	East West Center, E-W Center Box 1806, Honolulu, HI 96848
6.	Mr. Richard M. Howell (Rich)	Guam Fishermen's Cooperative Assn., P.O. Box 24023, GMF, Agana, Guam, Mariana Islands 96921
7.	Mr. Gerson Jackson	Marine Resources Division, Kosrae, Micronesia 96944
8.	Mr. Alvin Katekaru	Hawaii Division of Fish and Game, 1151 Punchbowl Street, Honolulu, HI 96813
9.	Mr. Joseph Matanane (Joe)	Bureau of Budget and Management Research, Office of the Governor, Agana, Guam 96910
10.	Mr. David Nada	Pacific Tuna Development Foundation, Hawaii State Department of Planning and Economic Development, P. O. Box 2359, Honolulu, HI 96804
11.	Mr. Robert T. Nishimoto (Bob)	Hawaii Division of Fish and Game, 1151 Punchbowl Street, Honolulu, HI 96813
12.	Mr. Toshiro Paulis	Marine Resources Office, Trust Territory of the Pacific Islands P.O. Box 1/602 Koror, Palau, Caroline Islands 96940
13.	Mr. Ramon ~~Echebei~~ Rechebei	Marine Resources Division, Trust Territory of the Pacific Islands, Saipan, Mariana Islands 96950
14.	Mr. Douglas Souter	Living Marine Resources, Inc., 7169 Construction Court, San Diego, CA 92121
15.	Mr. Joaquin P. Villagomez (Jack)	Marine Resources Development, Office of the Governor, Commonwealth of the Northern Mariana Islands, Saipan, Mariana Islands 96950
16.	Dr. Izadore Barrett Center Director	Southwest Fisheries Center, F/SWC, NMFS, NOAA, P. O. Box 271, La Jolla, CA 92038

2/11/81 Two copies to Chuck Johnston to forward to Yap--interested in constructing 5 buoys.

2/17/81 Copy to Bill Puleloa, Fisheries Officer, Majuro, Marshall Islands , TT w/DO letter