The CalCOFI Vertical Egg Tow (CalVET) Net

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ABSTRACT

The vertical egg tow (CalVET) net was devised by CalCOFI (California Cooperative Oceanic Fisheries Investigations) to estimate egg production in the central subpopulation of northern anchovy and similar fishes. This paper describes the sampling characteristics of the net and its interaction with physical and distributional features of the anchovy egg. Problems discussed include the horizontal patchiness of the eggs and intensity of their distribution, volume and depth distribution of the water filtered, egg retention, and towing characteristics of the net.

The mouth area of the CalVET net is 0.05 m^2; the tow is vertical to minimize the volume of water filtered per unit depth; the mesh size of 0.150 mm is selected for total retention of the anchovy eggs under all likely conditions. The mesh area of the net is three times the mouth area in the conical portion and five times the mouth area in the cylinder. The conical mesh is the minimum size necessary for highly efficient filtration, while the cylindrical portion reduces the probability of the net clogging during a single tow. A flowmeter detects sequential clogging of the net during a series of tows. The net is lowered and raised rapidly to diminish the effects of ship drift and undersea currents which impose uneven trajectories on the net. The net is probably not capable of sampling active larvae 5 mm or longer, owing to the small mouth size and the disturbance to the net's path from the towing wire.

Design and working drawings of the frame and net are included.

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HORIZONTAL PATCHINESS

We assume that eggs are released in the open sea by the gravid females of a northern anchovy school in close proximity to one another where they are fertilized by males. Previous samples of anchovy and sardine eggs indicated that most are found at densities of 1,000 to 5,000 eggs/m^2 when spawned, although only a small proportion of the samples actually contained eggs at these densities (Smith 1973; Smith and Richardson 1977:84). There is also evidence that most eggs are found in the upper 70 m of the water column (Ahlstrom 1959; Pommeranz and Moser 1983).

To shorten the sorting time for samples, we used a small net, 0.05 m^2 in cross section. To reduce the time spent sorting out the anchovy eggs from plankton, we used a vertical tow through the upper 70 m rather than a normal oblique tow, since a vertical tow captures far less extraneous plankton. Sample simulations on existing data for unstaged and staged anchovy eggs indicated that adequate sample precision could be obtained with 500 to 1,000 positive egg samples.

Previous studies by sonar, oblique plankton tow samples, and observations of spawning in the laboratory indicated three contributors to horizontal patchiness of anchovy eggs in the sea: 1) The act of fertilization; 2) the schooling habit; and 3) the propensity of schools to be contagiously distributed. The expected scale of horizontal patchiness from the act of fertilization is of the order of meters to tens of meters. The expected scale of horizontal patchiness from the schooling habit ranges from hundreds to thousands of meters. The expected scale of patchiness from the school group scale is of the order of kilometers to tens of kilometers. A study using eight replicate tows per station identified the school scale as the primary source of variance. Samples replicated at the same station indicated that only during the first half day after spawning was the fertilization swarm a significant source of variance relative to the school-size scale. To achieve statistical independence among adjacent samples, we decided to space the samples at least 3 km apart. The most usual spacing between samples has been 6 km in the offshore-onshore direction and about 16 or 32 km in the alongshore direction.

DEPTH DISTRIBUTION OF WATER FILTERED

The design objective of the CalVET tow was to filter a uniform and measured volume of water for each increment of depth from 70 m to the surface. The chief barriers to this goal are 1) ship drift and undersea currents, 2) clogging of the net, and 3) cyclic vertical motions of the towing wire caused by the heave and roll of the ship (Hewitt 1983).

The primary effect of ship drift and undersea currents is to distort the distribution of water filtered/unit surface area to a given depth. The ideal tow as designated here is to sample about 50 L water/m of depth to a depth of 70 m, or to near-bottom in shallow waters. First of all, ship drift and undersea currents diminish the depth attained with the fixed length of towing wire. For example, if the wire has strayed from the vertical by 30°, 70 m of wire will achieve only 61 m depth. Similarly 5° stray will affect the depth attained by less than 1 m. Secondly, ship drift and undersea currents change the angle of stray with time. For example, the net when vertical will filter 50 L water/m of depth, and at 30° the net will filter 58 L water/m of depth. Our usual experience is that the oversampling occurs in the upper layers relative to the deeper layers. In the recommended sample series all tows are repeated when the angle of stray has exceeded 30°.

The most important specification in this category is that the net must emerge from the water at right angles to the surface. It is known from horizontal samples at the surface that great concentrations of eggs may exist there, thus to drag the net along the surface toward the ship is to risk vast oversampling of the eggs.

The chief error caused by clogging of the meshes of the net is the relative undersampling of the shallow vs. deep water in an ascending vertical tow. It is conceivable that a net which is filtering 50 L/m of depth might clog in the upper layers and filter 40 or fewer liters per m of depth (Smith et al. 1968). The viscous resistance of the filtering surface requires that about three times as much mesh aperture as mouth aperture is required to filter water efficiently. For this reason the CalVET net is fitted with a truncated conical portion which contains three times as much mesh aperture area as the opening of the net. Since the mesh chosen is about 46% open area, the 0.15 m^2 aperture area of the conical section is achieved with 0.33 m^2 of mesh. In addition, to diminish the danger of the net changing filtration efficiency during the tow due to clogging, the net is fitted with a mesh cylinder with five times the mesh aperture area compared with the mouth opening of the net. This should be ample for a tow this length and with this mesh size (0.333 mm; see below) in coastal waters off California.

Filtering efficiencies of 97% are possible with simple net apertures. Efficiencies of 100% and more are possible with inverted conical net entrances like the original Hensen net. The complicated Hensen technique was not chosen because the filtration efficiency becomes a function of net speed, and the placement of the flowmeter in the flow section to obtain a representative sample of water filtered is poorly understood. Also, reverse cone structures increase the lateral drag of the net and worsen the consequences of ship drift and undersea currents. The design of the CalVET net makes clogging unlikely within a tow; thus the use of a flowmeter is not required to verify the constant filtration of water per unit depth. However, nylon nets are subject to sequential clogging in a series of tows, and flowmeters are recommended to ascertain and correct this problem. Deviations of flowmeter revolutions of 10% or more should be cause for exchange or careful washing of the net. For example, a calibration factor of 0.273 m/revolution of the flowmeter would predict that 256 revolutions be characteristic of a suitable tow from 70 m to the surface. Flow readings of 231 revolutions for the full tow, or 3.3 revolutions/m of wire out in shallow tows, would indicate that a sequence of clogging between tows may have begun.

Another retention problem with vertical net tows relative to horizontal and oblique tows is the direct connection of the net to the ship. The roll and heave of the ship could at times impart velocities to the net less than or in excess of design expectations. Several consequences are possible between motion of the net and the ship's roll and heave. The most serious problem is noted with simultaneous roll and heave downward when the net containing eggs approaches the surface (Hewitt 1983). Should the downward velocity exceed the recovery rate of the net, the net would collapse from below, there would be reverse filtration of water through the mesh apertures, and the eggs would be expelled from the mouth of the net. Probably the next most important danger is that when the net containing eggs approaches the surface, the simultaneous roll and heave upward will add the speed of the ship's motion to the already high speed of the net recovery wire. In this case, the eggs lying on the mesh might be ruptured or extruded through the mesh apertures. Quantitatively less important, perhaps, is the likelihood that a net at depth might be propelled upward fast enough to filter water and turn the flowmeter, thus oversampling the volume at that depth. The flowmeter is normally jammed against the mesh on the downward path. To diminish these effects, the net is lowered at 1-1.2 m/s and recovered at the same speed. In this way we achieve a depth of 70 m in 1 min and recover at the same speed. The net is stopped for 10 s at the bottom. Tows which vary substantially from this regimen should be repeated.

RETENTION OF ANCHOVY EGGS

The main considerations in retention of anchovy eggs by the CalVET net are the relative size of the egg, the mesh aperture, and the filtration velocity. The minimum dimension of the northern anchovy's egg is about 0.65-0.85 mm in February, and 0.55-0.80 mm in August (Smith and Richardson 1977:61). Such an object should be fully retained by mesh sizes <0.4 mm according to the "diagonal rule." The diagonal rule states that the minimum dimension of the object to be sampled should be greater than the diagonal of the mesh aperture. Absolute retention is affected also by the filtration velocity. For example, the CalVET net proceeds through the water at a nominal velocity of 70 m/min. The active filtering surface is about three times the net mouth area, thus the filtration velocity is 1.2 m/s divided by 3, or 0.4 m/s. This is a high filtration velocity relative to the normal oblique tows. Thus the net mesh size for the CalVET was selected to be 0.150 mm. The main reason for the high net velocity is to diminish the time for errors of ship drift and undersea current to accumulate.

DESIGN AND WORKING DRAWINGS OF THE CalVET NET

The CalVET frame and net are much smaller than traditional ichthyoplankton nets: 0.25 m diameter mouth opening (0.05 m^2 mouth area) and the total length of the net is <1.5 m. The net is lowered to a depth of 70 m and retrieved vertically at 70 m/min; strict controls govern the field procedures, and a tow is rejected if the wire strays too far from the vertical or if the retrieval rate is too fast or too slow. The results from field testing the gear in 1979 indicated a very high degree of fidelity among eight replicates at a single station; the test was conducted over 70 stations and within a 200-fold range in egg abundance.

Figures 1-5 describe the bongo-type (PAIROVET) version of the CalVET sampler. The frame was designed to facilitate comparison of nets constructed of various materials and to provide replicate observations when using similar nets; it has become one of the standard samplers used by the Southwest Fisheries Center. The frame is constructed of 6061-T6 aluminum with stainless steel fittings. The nets are nylon mesh attached to the frame with adjustable stainless steel strapping. The cod end is removable and attached to the rest of the net by means of a plastic collar. The net and cod end are sewn inside a "sleeve" constructed of 2-mm mesh vinyl-coated polyester (not shown) to protect them from abrasion.

Nets of several mesh sizes have been used by the Southwest Fisheries Center. All have been constructed using the dimensions shown in the figure; total area of net material is 0.95 m^2. With the exception of the 0.035-mm mesh, all of the net materials have approximately the same porosity, i.e., the portion of the net area which is open. Smith et al. (1968) suggested that adequate filtering efficiency can be maintained in coastal waters if the ratio of aperture area to mouth area is at least 3.4 for a net of the proportions described. Thus, these nets may be expected to perform well with the exception of the very fine (0.035 mm) mesh net which may clog in turbid coastal waters (Table 1).

Table 1.—Ratio of aperture area to mouth area for various net mesh sizes. Nets with mesh <0.333 mm are protected by a 2-mm mesh nylon sheath. See text.

Mesh (mm)	Total area (m^2)	Porosity	Aperture area (m^2)	Aperture area/ mouth area
0.035	0.95	0.16	0.15	3.04
0.075	0.95	0.45	0.43	8.55
0.150	0.95	0.51	0.48	9.69
0.250	0.95	0.49	0.47	9.31
0.333	0.95	0.46	0.44	8.74
0.505	0.95	0.49	0.47	9.37

LITERATURE CITED

ALHSTROM, E. H.

1959. Vertical distribution of pelagic fish eggs and larvae off California and Baja California. Fish. Bull., U.S. 60:106-146.

HEWITT, R.

1983. Roll, heave and vertical ichthyoplankton tows. Ocean Sci. Eng. 8:41-51.

POMMERANZ, T., and H. G. MOSER.

1983. Vertical distribution study. R/V *Ellen B. Scripps*, March 19-April 4, 1980. Technical tow data and environmental observations and preliminary data lists and summaries of vertical distribution of northern anchovy (*Engraulis mordax*) eggs and larvae. Southw. Fish. Cent., Natl. Mar. Fish. Serv., NOAA, P.O. Box 271, La Jolla, CA 92038, Admin. Rep. LJ-83-01, 368 p.

SMITH, P. E.

1973. The mortality and dispersal of sardine eggs and larvae. Rapp. P.-v. Reun. Cons. int. Explor. Mer 164:282-292.

SMITH, P. E., R. C. COUNTS, and R. I. CLUTTER.

1968. Changes in filtering efficiency of plankton nets due to clogging under tow. J. Cons. Perm. Int. Explor. Mer 32:232-248.

SMITH, P. E., and S. L. RICHARDSON.

1977. Standard techniques for pelagic fish egg and larva surveys. FAO Fish. Tech. Pap. 175, 100 p.

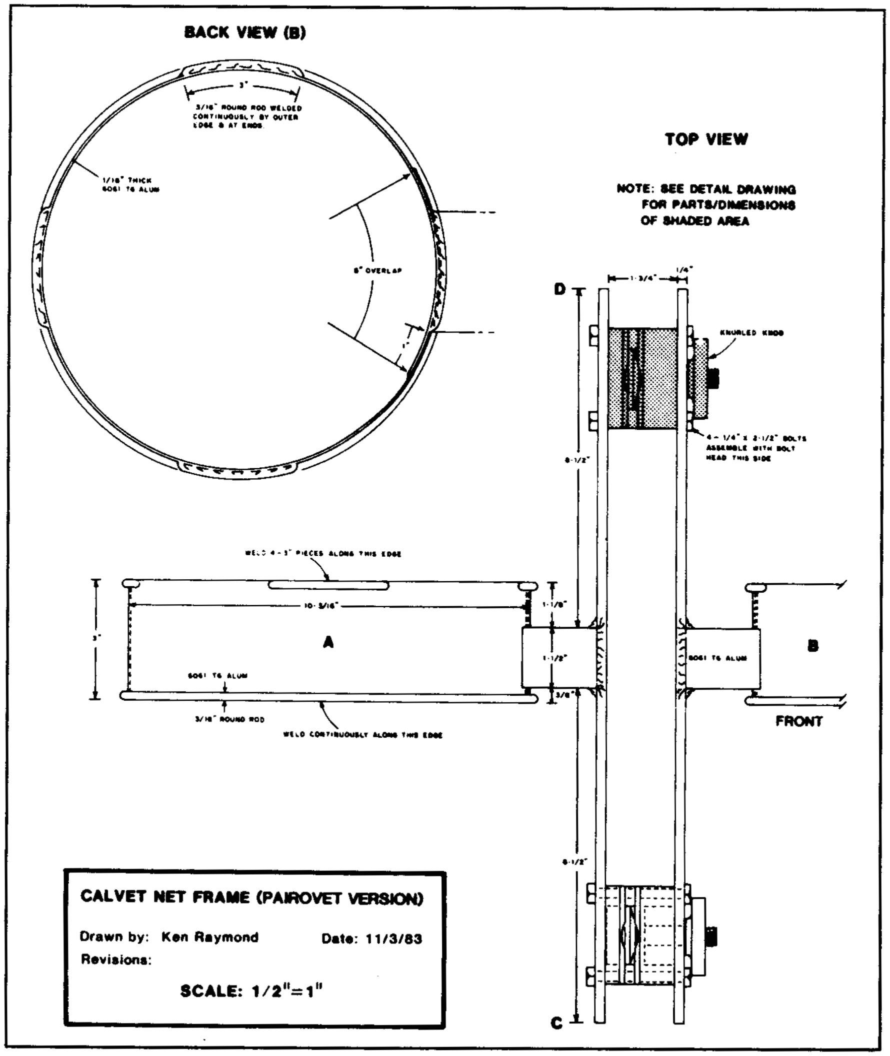

Figure 1.—Back and top view of PAIROVET version of CalVET net frame.

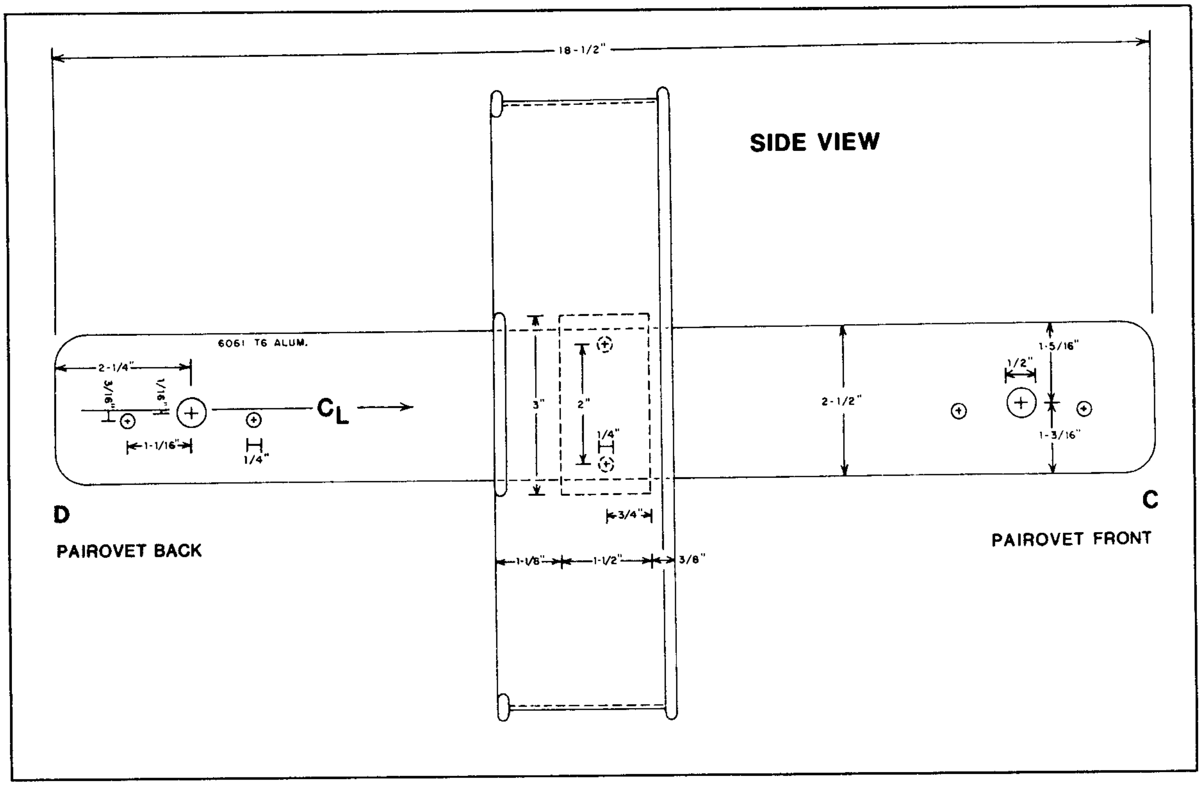

Figure 2.—Side view of PAIROVET net frame.

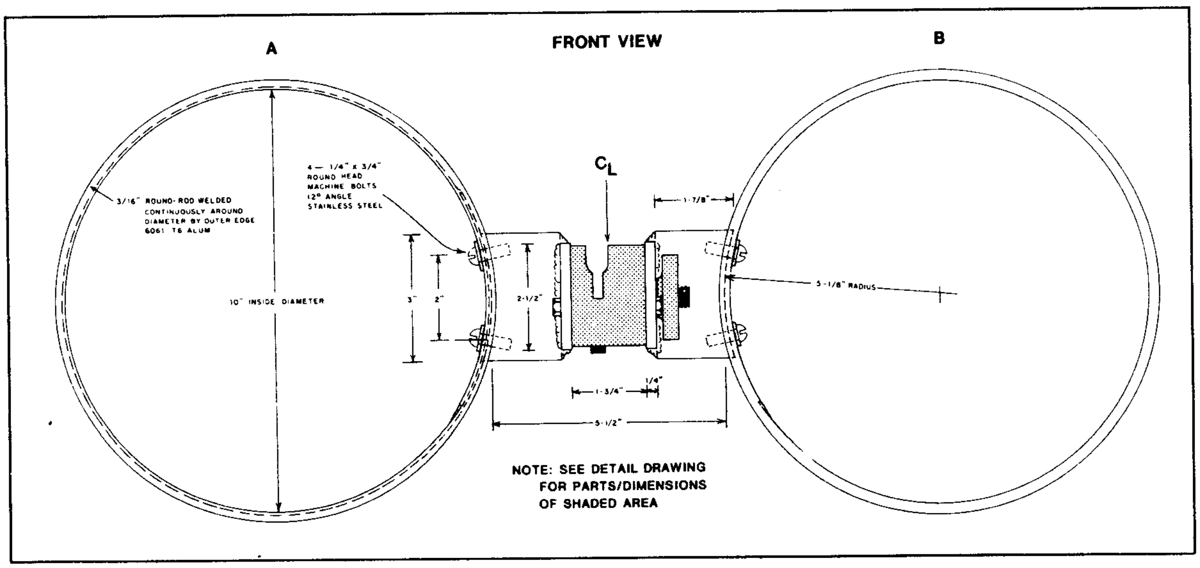

Figure 3.—Front view of PAIROVET net frame.

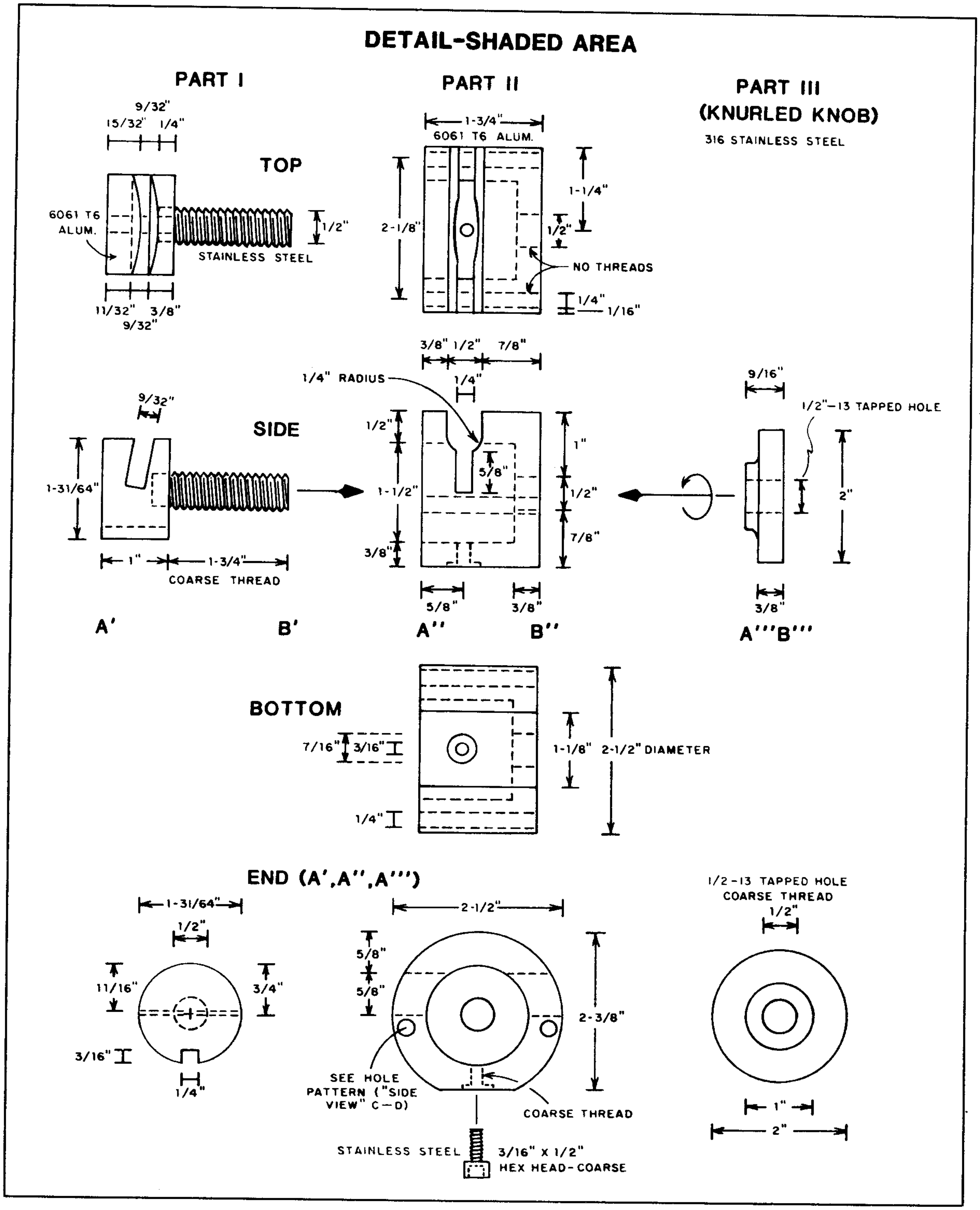

Figure 4.—Detailed view of wire attachment for PAIROVET net frame. "Shaded area" refers to Figure 3.

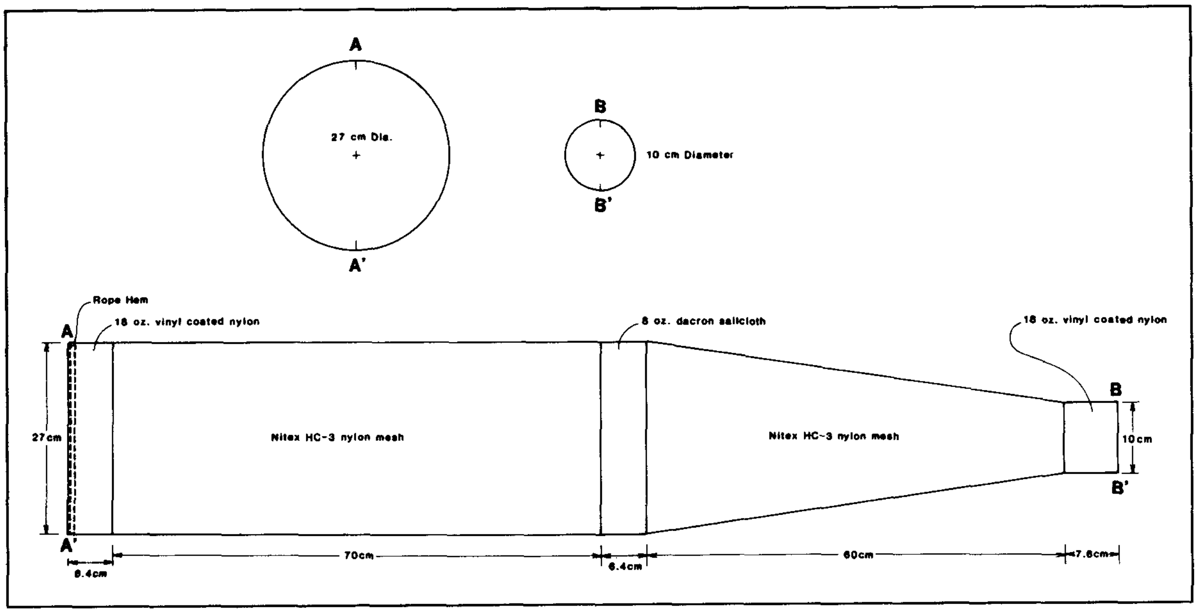

Figure 5.—CalVET net dimensions. For nets with mesh sizes <0.333 mm, a protective sheath of 2-mm mesh nylon is used. See Table 1.