CalCOFI Rep., Vol. XXI, 1980

FREE-FALL PARTICLE COUNTER FOR OCEAN SURVEYS

REUBEN LASKER AND JOHN C. BROWN
National Marine Fisheries Service
Southwest Fisheries Center
La Jolla, CA 92038

ABSTRACT

For a study of particles in the sea as potential food organisms for larval anchovies (Lasker 1975, 1978), a survey method was needed to profile particle concentrations with depth rapidly during California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys.

To do this, a microprocessor-based free-fall particle counter (FFPC) was designed and constructed (Brown 1977) based on the well-known principle that a particle passing into an electrical field in an electrolyte causes a change in electrical properties if resistivity of the particle differs from that of the electrolyte. The widely used Coulter Counter® is an example of an instrument based on this principle.[1] In this report, laboratory calibration and a field test of the FFPC are described as well as modifications to the instrument that permit fast deployment of the probe, shipboard display, and printing of the data.

RESUMEN

Para un estudio de partículas en el mar como organismos potenciales de alimentación para larvas de anchoveta (Lasker 1975, 1978), se necesitaba un metodo rápido para poder perfilar concentraciones de partículas con la profundidad, durante los cruceros de reconocimiento de CalCOFI.

Para hacer ésto, un contador de partículas de caída libre basado en un microprocesador fue diseñado y construido, basado en un principio bien conocido de que una partícula, al pasar por un campo eléctrico en un electrolito, causa un cambio en las propiedades eléctricas si la resistividad de la partícula difiere de la del eléctrolito. Un ejemplo de un contador que está basado en este principio y que se usa mucho es el Coulter Counter®[1]. En este trabajo, se dèscribe la calibración en el laboratorio y la prueba práctica del contador, así como modificaciones del instrumento que facilitan el despliegue rápido de la sonda, una muestra a bordo, y la imprenta de los datos.

INTRODUCTION

In a series of recent papers, Lasker (1975, 1978, 1979) described the importance of particle size and concentration with depth and area in relation to particulate feeding by anchovy larvae. These studies showed that information on the distribution of particles of about 20-40 μm in "effective diameter"[2] could be related to survival of anchovy larvae and thus to the size of future year classes. The usual technique for obtaining particle size and concentration data has been by overside deployment of a hose and submersible pump. This required considerable ship time and manpower. Using a pump, particle size and concentration could only be obtained by retrieving some of the water from specific depths and by counting particles suspended in the water with a Coulter Counter in the shipboard laboratory. This tedious procedure provides very few data points in vertical transects, nor does it give information on patchy distribution of particles. It became evident in our work that a method was needed that could provide for a continuous record of particle size and concentration with depth quickly and at finer depth intervals. A microprocessor-based system with a free-fall probe was designed by Brown (1977) to collect this information. This paper describes recent engineering innovations of the system, a field test under sea-going conditions, and laboratory calibration.

OPERATION

We have called this instrument a free-fall particle counter (FFPC), althrough it is tethered with a conducting cable to relay information to a dedicated microprocessor aboard the ship. The instrument is designed to resolve particle layers of at least 0.2 m thick in a vertical profile to 100 meters. In operation, the entire procedure, including deployment of 100 m of conducting cable and retrieval, takes about three to four minutes, although the actual data collection occurs in a pre-set 100 seconds during the fall of the probe. If the probe sinks too slowly, it provides more information for each depth interval, but because the pre-set 100 seconds may have elapsed too soon, it will not collect data to the desired depth. Sinking speed is a function of the amount of lead weight added to the bottom of the probe and a variety of uncontrollable ocean-related factors, e.g. drift and currents. In practice, a winch (Figure 1), designed specifically for the sensor probe (Figure 2) and its cable, is attached to the ship's bucket. As the sensor falls and the cable is payed out, the information obtained by the falling sensor is relayed to the microprocessor where it is stored on tape and displayed on a video screen as particle concentration by size of particle and depth in addition to a time and date record

[1]Mention of trade names does not imply endorsement by the National Marine Fisheries Service.
[Manuscript received 17 January 1980.]

[2]Particles, regardless of shape, are counted as if they were spherical, hence sizes are recorded as "effective diameters."

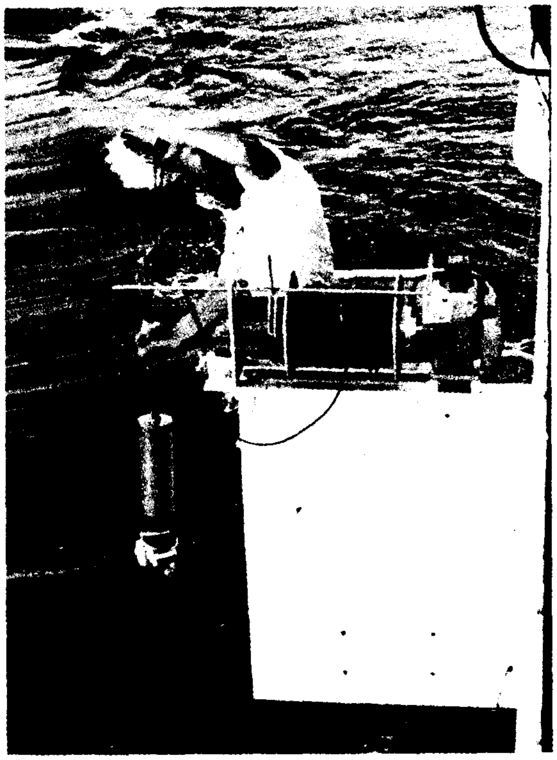

Figure 1. Sensor probe and winch for free-fall particle counter (FFPC). Winch is equipped with manual level wind and clutch. Operator is standing in ship's bucket.

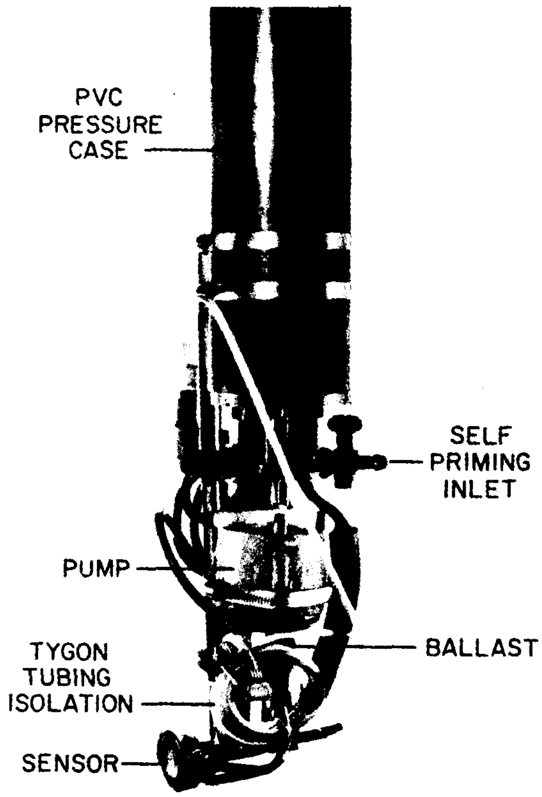

Figure 2. Free-fall particle counter (FFPC) sensor probe (after Brown 1977).

(Figure 3). The video display provides an immediate assessment of the drop and informs the operator whether or not the cast needs to be repeated. The microprocessor is programmed to accept and record the data on a cassette tape, then to relay the information from each cast to a Hewlett Packard 9825 mini-computer, which in turn is programmed to print the information in graphic form by size concentration and depth. For each cast, as many as seven particle size ranges and concentrations can be obtained with depth, and each size range and concentration can be printed on a separate graph aboard ship. Similarly, a digital output is available either of all the data collected or averaged for specified depth intervals (e.g. 1 m, 5 m, etc.).

A fine hole drilled into a fiberglass disk suffices for the sensor pore intake. We have found that a pore of 400-μm diameter can provide information on particles ranging in size from 20 to 100 μm in effective diameter. Other size pores can be used but have not yet been tested and are not reported on here. Clogging of the 400-μm pore is rarely a

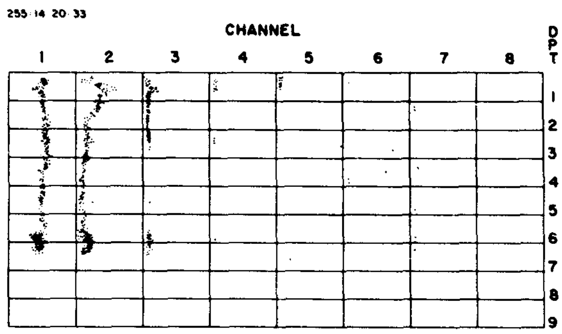

Figure 3. Diagram of a typical video display. Depth (DPT) is given on the ordinate. Day of the year (255) and time of day are shown on the screen at the upper left hand corner. Each dot is an indication of the number of particles of a particular size class sensed by the probe for 0.2 second. Channel 1 is not used because of electrical interference. With a 400 μm pore, Channel 2 receives impulses from particles ranging in effective diameter from 20.2-25.3 μm; Channel 3, 25.4-31.9 μm; Channel 4, 32.0-40.2μ m; Channel 5, 40.3-50.7 μm; Channel 6, 50.8-63.9 μm; Channel 7, 64.0-80.5 μm; Channel 8, 80.6-100.0 μm. The data from this cast are shown as a cumulative curve, third from the left in Figure 6.

problem since the amount of water pulled through the pore during any one descent is about 50 ml and usually has very few large particles in it.

CALIBRATION

Figure 4 illustrates a laboratory calibration of the sensor probe against the Coulter Counter model T_A using a mature culture of the dinoflagellate, *Gymnodinium splendens*, or 30-40 μm polystyrene beads. When particle concentrations are below 250-300 particles/ml, there appears to be no coincidence of counts, and particle concentrations can be obtained directly without resorting to a calibration curve. There is an obvious coincidence problem above 300 particles/ml, and corrections must be made whenever this is encountered. However, rarely are such high concentrations of particles >20 μm diameter found in California waters.

FIELD TEST

A typical series of casts were taken about 10 miles off the coast of San Diego on 12 September 1979 in rapid succession. Each cast and retrieval took about five minutes with the ship drifting slightly southeast. The positions of the ship are shown in Figure 5, top. There was a sharp thermocline between 7 and 18 m and a strong pycnocline at 12 m (S = 33.5 °/oo, T = 15.5°C; Figure 5, bottom). Figure 6 is a summary of total particles from 20-100 μm in effective diameter with depth taken at approximately 5-minute intervals. Note that the pycnocline at 12 m effectively marks the lowest boundary of a broad particle layer in the surface water. Reproductions of the computer printout are given in Figure 7. With slight changes

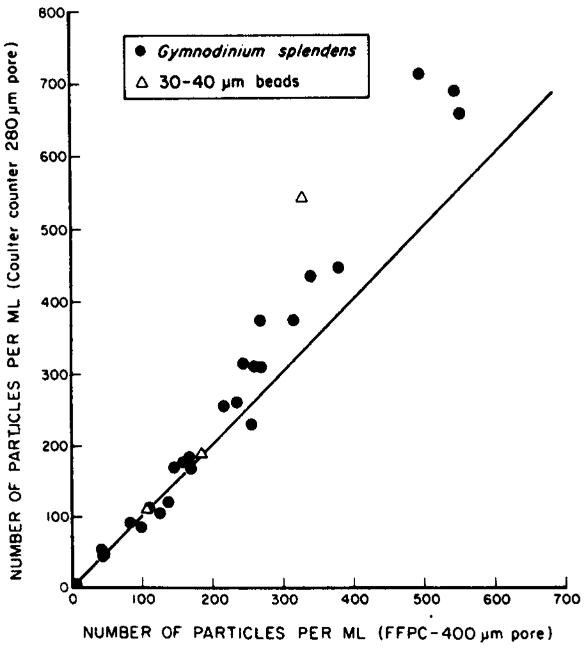

Figure 4. Calibration of free-fall particle counter (FFPC) with 400 μm pore against Model T_A Coulter Counter, 280 μm pore. Microscope counts were used to verify Coulter Counter output.

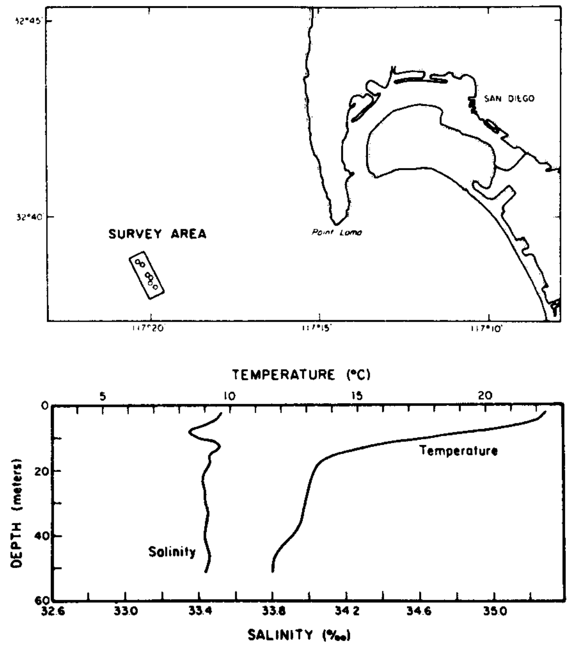

Figure 5. Top, ship positions for repetitive free-fall particle counter (FFPC) sampling; bottom, salinity and temperature profiles taken at first station.

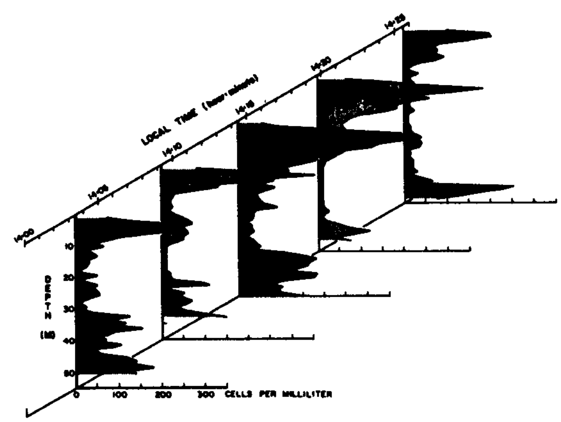

Figure 6. Total particles from 20-100 μm effective diameter with depth taken at approximately 5-minute intervals. Ship positions are shown in Figure 5.

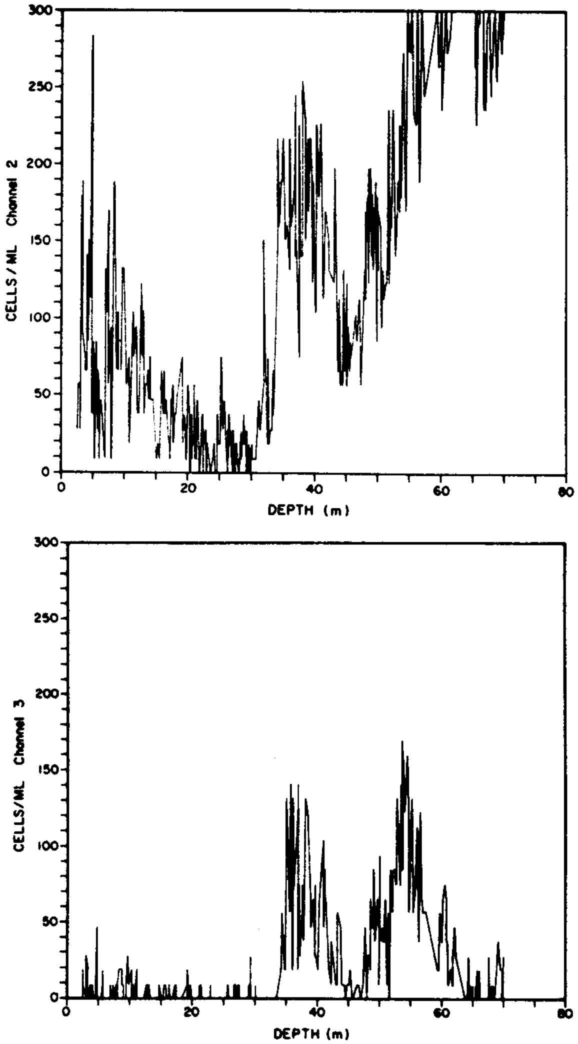

Figure 7. Graphic output from a single cast using the Hewlett Packard 9825 mini-computer and peripheral unit: Top, Channel 2, 20.2-25.3 μm; bottom, Channel 3, 25.4-31.9 μm particles.

in the Hewlett Packard 9825 program, specific size ranges can be printed separately or summed to give cumulative size ranges and concentrations with depth.

DISCUSSION

There are several operational advantages unique to this instrument. These are 1) each profile of particle concentration with depth to 100 m can be made in less than five minutes; 2) particle sizes may be differentiated by seven usable electronic channels; the size displayed in each channel may be varied by using different pore sizes; 3) an immediate plot of particle concentration by size and depth is available on shipboard by interfacing the microprocessor with a mini-computer (Hewlett Packard 9825) and its peripheral plotter and printer; 4) the submersible portion of the unit is portable and replaceable; and 5) the water drawn through the pore (about 50 ml) can be retrieved from the intake tube and preserved for later study.

Two major disadvantages to the instrument are evident: 1) species of phytoplankton and microzooplankton cannot be assigned to a particular depth; and 2) intake volumes with pores to 400 μm are small for any single cast, thus large particles (>100-μm diameter) are sampled too infrequently for statistical treatment.

LITERATURE CITED

Brown, J.C. 1977. A microprocessor-based oceanographic particle data collection system. Oceans '77 Conference Record, MTS-IEEE, Vol. 1, p. 3C1-3C3.

Lasker, P. 1975. Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. Fish. Bull., U.S. 73:453-462.

__________. 1978. The relation between oceanographic conditions and larval anchovy food in the California Current: identification of factors contributing to recruitment failure. Rapp. P.-v. Réun. Cons. int. Explor. Mer 173:212-230.

__________. (in press). Factors contributing to variable recruitment of the northern anchvy (*Engraulis mordax*) in the California Current: contrasting years, 1975 through 1978. Rapp. P.-v. Réun. Cons. int. Explor. Mer 178.