The Australian Clarke–Bumpus Sampler and Calibration Tank

D. J. TRANTER

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Summary

A description is given of a modified Clarke–Bumpus sampler and of a tank used to calibrate the flowmeter. The sampler differs from the American model in being stronger, more reliable, and easier to use. The flowmeter can be calibrated in the tank at velocities up to 5 kt, the water entering the meter through a rounded flare to simulate normal flow conditions. The flow is measured at the exit from the tank where the water passes over a 90° V-notch.

I. Introduction

The Clarke–Bumpus sampler has been used in Australian coastal and oceanic zooplankton investigations since 1959 (Tranter 1962). The first unit was obtained from Plymouth, England, in 1953 and differed from that described by Clarke and Bumpus (1950), the modifications being derived from the "measuring plankton net" of Harvey (1935). The Plymouth sampler was never described, but was noted by Paquette and Frolander (1957) and is shown in Figure 6 of the paper of Barnes (1959). The flowmeter was sensitive but fragile. The counting mechanism, housed within the metal tube, was read through a Perspex window. The present author found that the propeller vanes were easily damaged in rough weather and that eventual wear in the counting mechanism led to reading errors of a serious nature. A wooden frame, straddling the net and providing a means of attachment for the cod end, replaced the metal extension rod which is still a feature of American-made samplers. The wooden frame, through its buoyancy and planing effect, removed the need for lateral paravanes.

From the Plymouth prototype, several units were constructed in our workshops. These units were modified continually in the light of field experience until it became necessary to make new ones. The designs incorporated the more desirable features of the American and Plymouth samplers, together with the innovations of Paquette and Frolander (1957) and the modifications dictated by our own experience.

It was our aim to evolve a zooplankton sampler analogous to the Nansen water bottle, that is, a mechanical instrument small enough to be handled by one man, rugged enough to withstand the normal rigours of oceanographic field work, and reliable enough to operate in series. A successful opening–closing action is more difficult to devise for horizontally towed plankton samplers than for a Nansen cast. First, one is dealing with a double-action, 2-messenger system; secondly, the wire

* Division of Fisheries and Oceanography, CSIRO, Cronulla, N.S.W.

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angle varies from 30° to 60° during a tow, with associated problems of messenger delivery. Most closing samplers have given trouble, and the Clarke–Bumpus model is no exception. However, with sufficient attention to detail, this sampler will operate with complete reliability.

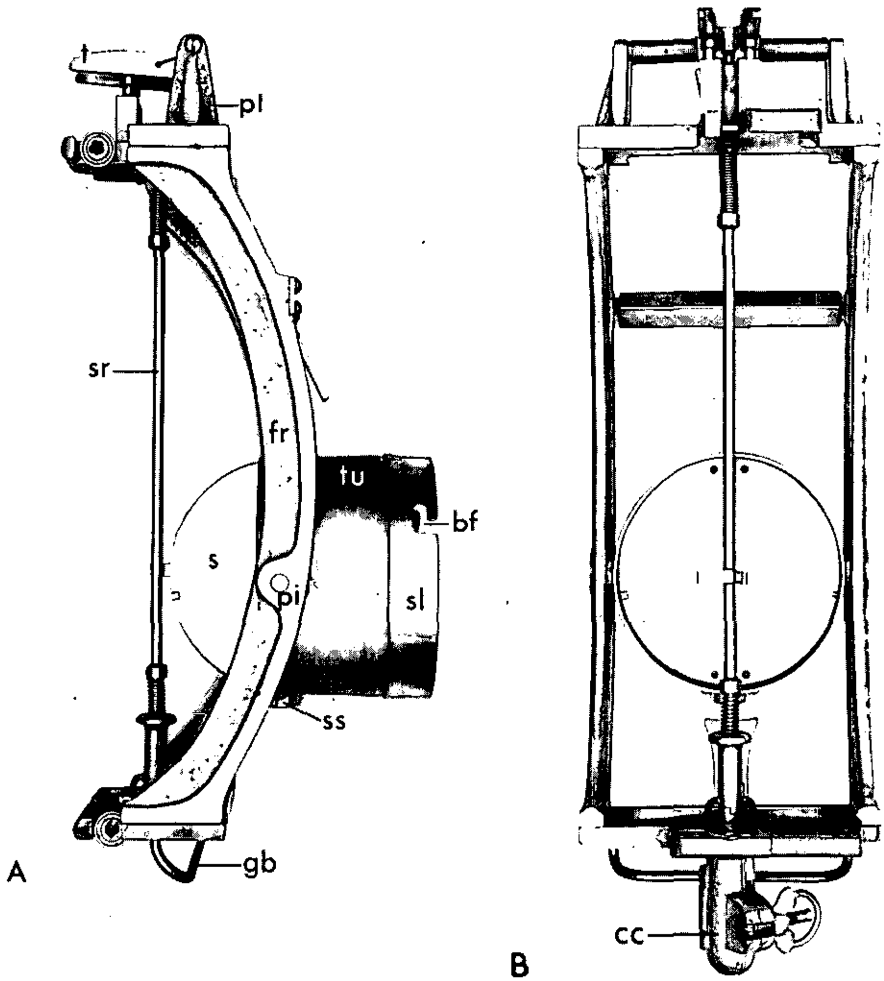

Fig. 1.—Forward section of the sampler. (*A*) Lateral view; (*B*) anterior view.
bf, bayonet fittings; cc, cable clamp; fr, frame; gb, guard bar; pi, pivots; pl, pillars; s, shutter; sl, sleeve; sr, shutter rod; ss, shutter spring; t, trigger; tu, tube.

Since its development, the sampler has been tested in the field (Tranter 1962; Barnes and Tranter 1965) and in the laboratory, and a tank was built for calibrating the flowmeter. The construction of the sampler and of the calibration tank is described in detail in the present paper.

II. Sampler

(*a*) *General Features*

Early experience with Clarke–Bumpus samplers showed that parts were susceptible to damage and that the opening–closing mechanism was sensitive to influences other than the impact of the messenger. These weaknesses had to be eliminated in the new sampler and, in addition, other requirements had to be met. To exploit its full potential, the instrument was designed to carry a depth recorder, an accurately calibrated flowmeter was to be used, and samplers were to be used on cables up to 7 mm in diameter. To permit all this, the original design was altered in one major respect. The structure was separated into two parts, namely, a forward section comprising the frame and opening–closing system, and an after section (tailpiece) comprising flowmeter, depth recorder (detachable), net, bucket, and tail struts (see Figs. 1 and 2).

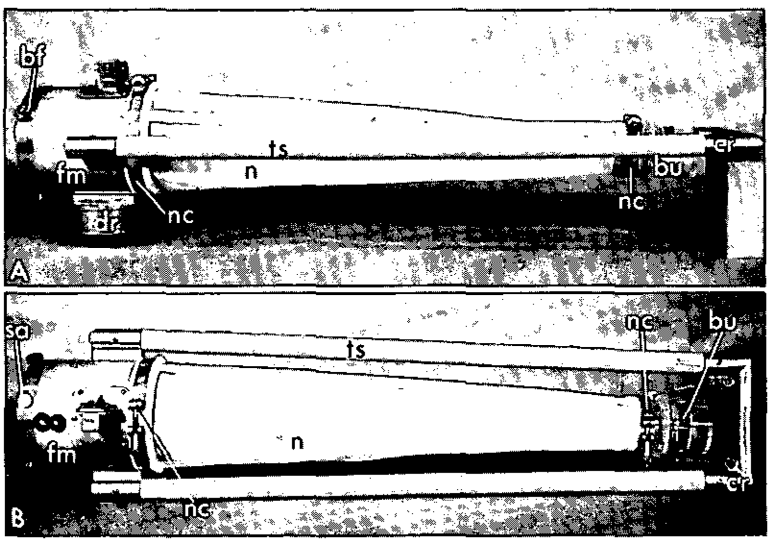

Fig. 2.—After section of the sampler. (*A*) Lateral view; (*B*) dorsal view. bu, bucket; bf, bayonet fittings; cr, crosspiece; dr, depth recorder; fm, flowmeter; n, net; nc, net clamps; sa, safety screw; ts, tail struts.

(*b*) *Forward Section*

Tube (see Fig. 1).—The tube (length $3\frac{1}{2}$ in.) is made from 16 gauge tubing, in stainless steel in preference to brass for greater strength. Brass is susceptible to distortion which, for example, can cause inaccurate seating of the shutter, allowing water to pass through the "closed" sampler.

Frame (see Fig. 1).—The frame is cast in brass, strengthened at the pivot points. Should the frame bend out of shape, pressure might be brought to bear upon the rotating rod ("shutter rod") which straddles it, thus interfering with the opening–closing mechanism.

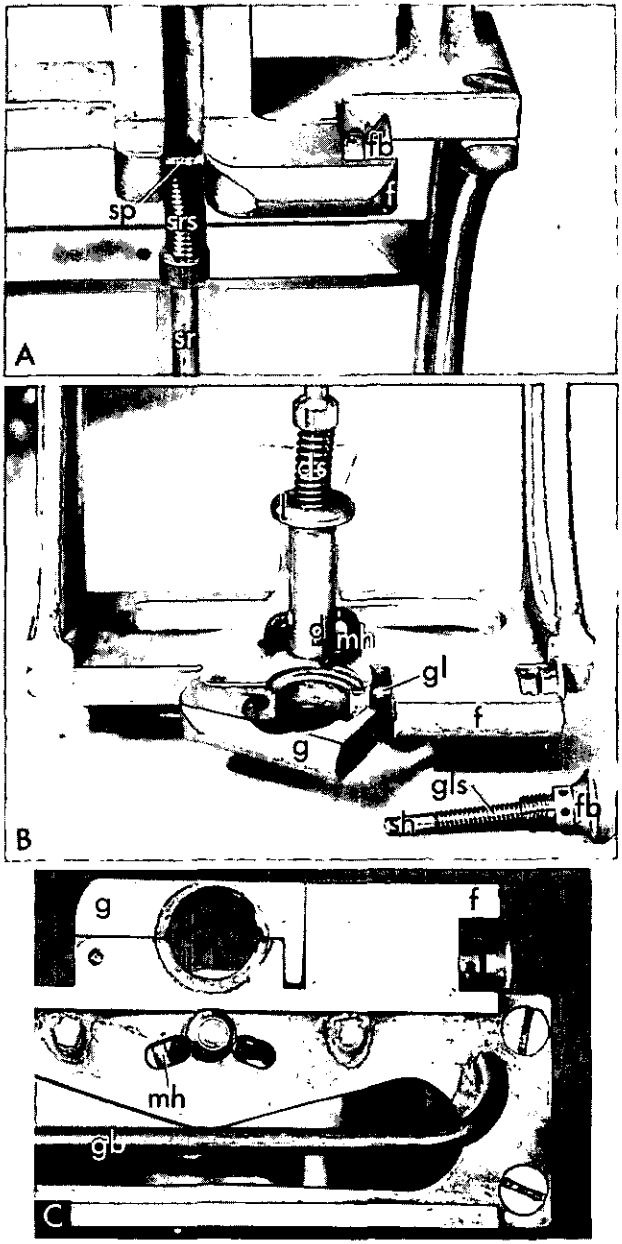

Fig. 3.—Parts of the forward section. (*A*) The spring pin and its protective fairing; (*B*) the gate lock and dog clutch—constructional details are evident in a second gate lock lying separately at bottom right; (*C*) frame of the forward section (ventral view), showing gate, gate lock, protective fairing, and guard bar.

d, dog clutch; ds, dog clutch spring; f, fairing; fb, finger button; g, gate; gb, guard bar; gl, gate lock; gls, gate lock spring; l, lifter; mh, messenger hooks; sh, shaft; sp, spring pin; sr, shutter rod; srs, shutter rod spring.

Spring Pin and Gate Lock (Figs. 3(*A*) and 3(*B*)).—Incorporated in the frame castings are protective fairings for the spring pin (upper part of frame) and the gate lock (lower part). These lie in exposed positions and, if the finger buttons are accidentally knocked, their shafts are easily bent. For swift and safe attachment of samplers to the cable, both spring pin and gate lock should be positive in action yet easy to manipulate. The shafts are of $\frac{9}{64}$-in. stainless steel rod, the springs (stainless steel) are strong, and the finger buttons are large, smooth, and convenient to handle.

Shutter Spring (see Fig. 1(*A*)).—In the American sampler, the shutter spring is helically wound upon a projecting pivot post which is easily damaged. In the Australian sampler, no post is necessary because the spring is conically wound and encased in a grease-filled capsule fitting snugly against the barrel.

Trigger (Figs. 1 and 4(*C*)).—The trigger system of the Clarke–Bumpus sampler has given a great deal of trouble. Paquette and Frolander (1957) introduced badly-needed changes, and their ideas have been extended in the Australian sampler to give even greater precision of operation. The trigger of the American sampler (Paquette and Frolander, Fig. 2) pivots upon a horizontal rod (trigger shaft) supported by two lateral pillars and is controlled by a restraining spring anchored to the after extension of the trigger which projects 2 in. beyond the trigger shaft. In the Australian sampler, the pillars are reduced in height to $1\frac{3}{4}$ in., the after extension of the trigger is eliminated, and the controlling springs are wound upon the trigger shaft. Each spring is anchored upon both the lateral face of the trigger and the base of the pillar supporting the trigger; the tension can be altered in the field by winding or unwinding. Such control has proved to be one of the most important means of rectifying malfunctions of the opening–closing system.

Indexing Mechanism (Fig. 4).—The other troublesome feature of earlier models was the "indexing mechanism" on top of the vertical shutter rod (Paquette and Frolander, Fig. 2). Neither Clarke and Bumpus nor Paquette and Frolander emphasized that the function of the "escapement rod" is to ensure that the shutter will rotate only 90° in response to the first messenger, no matter what the tension in the springs controlling shutter, shutter rod, and trigger. The escapement rod, lying between two lugs at right angles to each other upon the collar, controls overall rotation and ensures that the trigger bar returns to the collar to engage the second lug after the impact of the first messenger (see Fig. 4(*B*)). This is done by angling the escapement rod towards the collar and adjusting the collar height by washer and holding screw, leaving no more than sufficient clearance for the escapement rod to pass the returning trigger bar. Such a simple adjustment reduces the possibility that a series of samplers might be towed, unwittingly, in the closed position.

Messenger Attachment (see Fig. 3(*B*)).—As Paquette and Frolander have suggested, messengers are more easily loaded if the finger assembly from which the messenger loops are suspended is fitted with a retractable "dog clutch". In the Australian sampler, for greater convenience, the dog clutch is provided with a "lifter" which houses the dog clutch spring. To reduce the danger of incorrect messenger loading, the two messenger hooks, which are of slightly unequal length, are painted different colours, with corresponding colours for appropriate messengers.

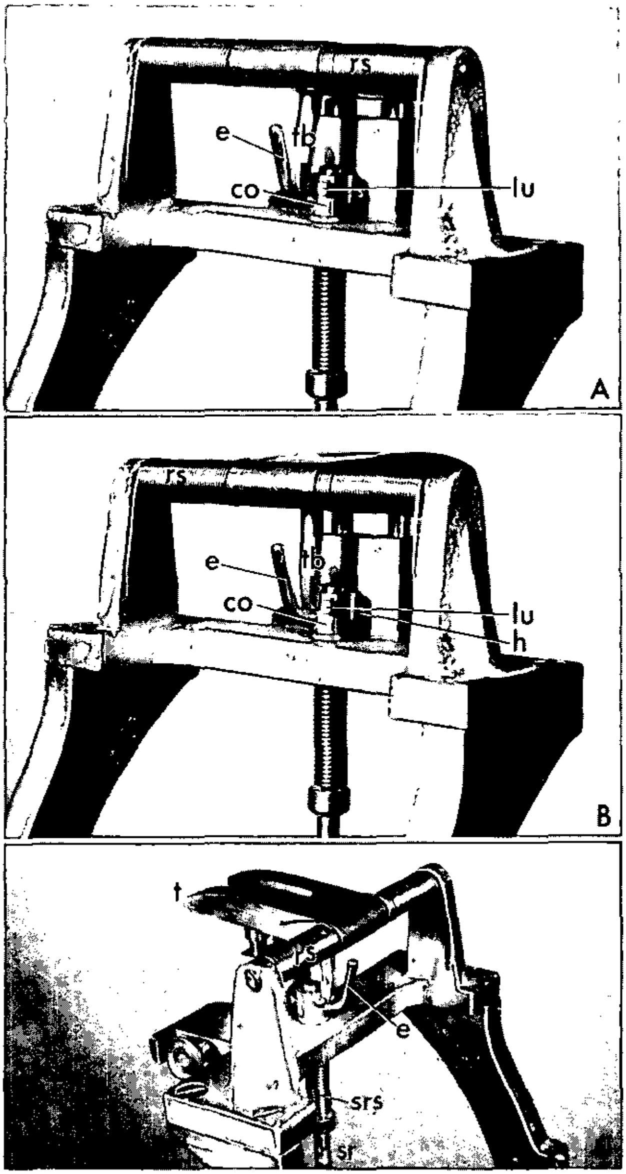

Fig. 4.—The indexing mechanism and the trigger, showing the collar, with its escapement rod and lugs, in relation to the trigger bar. (*A*) Position immediately after the first messenger strikes—the trigger is depressed, freeing the trigger bar from the first lug; rotation of the collar is arrested by the escapement rod; (*B*) position an instant later—the trigger bar has slid down the incline of the escapement rod and is about to escape past it; thence, the collar will continue its rotation until arrested by the trigger bar at the second lug, in which position it will remain until the second messenger strikes; (*C*) the trigger in lateral view, showing the anchoring of its restraining springs.

co, collar; e, escapement rod; h, holding screw; lu, lugs; rs, restraining spring; sr, shutter rod; srs, shutter rod spring; t, trigger; tb, trigger bar.

Guard Bar (see Figs. 1 and 3(*C*)).—Clarke and Bumpus provided a guard to prevent the loops suspending the messengers from becoming fouled on the cable clamp. This was a curved rod spanning a space of 2½ in. immediately behind the gate-lock. However, this guard was often ineffective and has been replaced by a wider (4½-in.) bar spanning practically the entire width of the frame.

Cable Clamp (Fig. 5).—The hinge and bolt of the original cable clamp were weak. This was most evident when great pressure was used on the thumbscrew, not so much to ensure safe attachment to the cable as to close the split collar far enough to fit within the gate lock of the sampler. This system is basically unsound, since it has the associated limitation that different clamps need to be used for cables of different diameter. The trouble can be avoided by casting one half of the clamp with the complete collar attached, leaving a slit just wide enough to take the largest cable likely to be used.

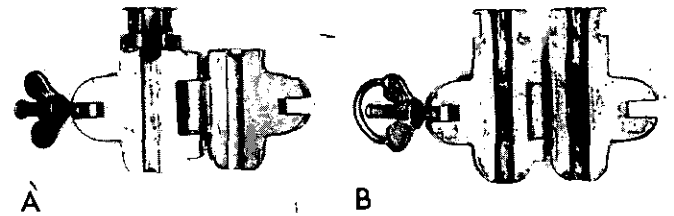

Fig. 5.—Clamps. (*A*) A universal cable clamp; (*B*) the clamp routinely used for 7-mm cable.

(*c*) *After Section*

Tube (see Figs. 2, 6(*B*), and 6(*C*)).—The tube of the after section is 6 in. long and houses the flowmeter. It is constructed of the same material as the tube of the forward section, the rigidity of the stainless steel ensuring that the propeller blades can extend almost to the walls of the tube without becoming fouled upon it.

Attachment (see Fig. 2).—The tube fits into a 1-in. sleeve welded to the after end of the forward section and attaches by a 3-point bayonet fitting. A safety screw through both sleeve and tube ensures that the bayonet fitting remains correctly positioned.

Flowmeter (Fig. 6).—The flowmeter in the Australian sampler represents a radical departure from both the Plymouth and American models. Sturdiness, streamlining, and simplicity are emphasized. The propeller, in the form of a helical screw, presents minimal resistance to the water passing through, and at the same time gives maximal thrust at low water velocities. Although sensitivity was not a major requirement, the flowmeter compares favourably in this respect with the American one.

The propeller has four blades mounted on a central boss, 1 in. long by ½ in. in external diameter, held in place upon a 3-in. stainless steel shaft by a streamlined nut. The propeller shaft drives a bevel pinion into a right-angle bevel gear with a 3 : 1 reduction, the gears being widely available under the trade name "Meccano" (30a and 30c).

The forward propeller bearing is of monel metal, $\frac{3}{16}$ in. in diameter by $\frac{1}{4}$ in. long; the thrust is taken at the after (bevel pinion) end on a needle bearing. The drive shaft from bevel gear to counter uses a needle bearing at the gear end and a plain $\frac{1}{8}$-in. diameter bronze bearing at the counter end.

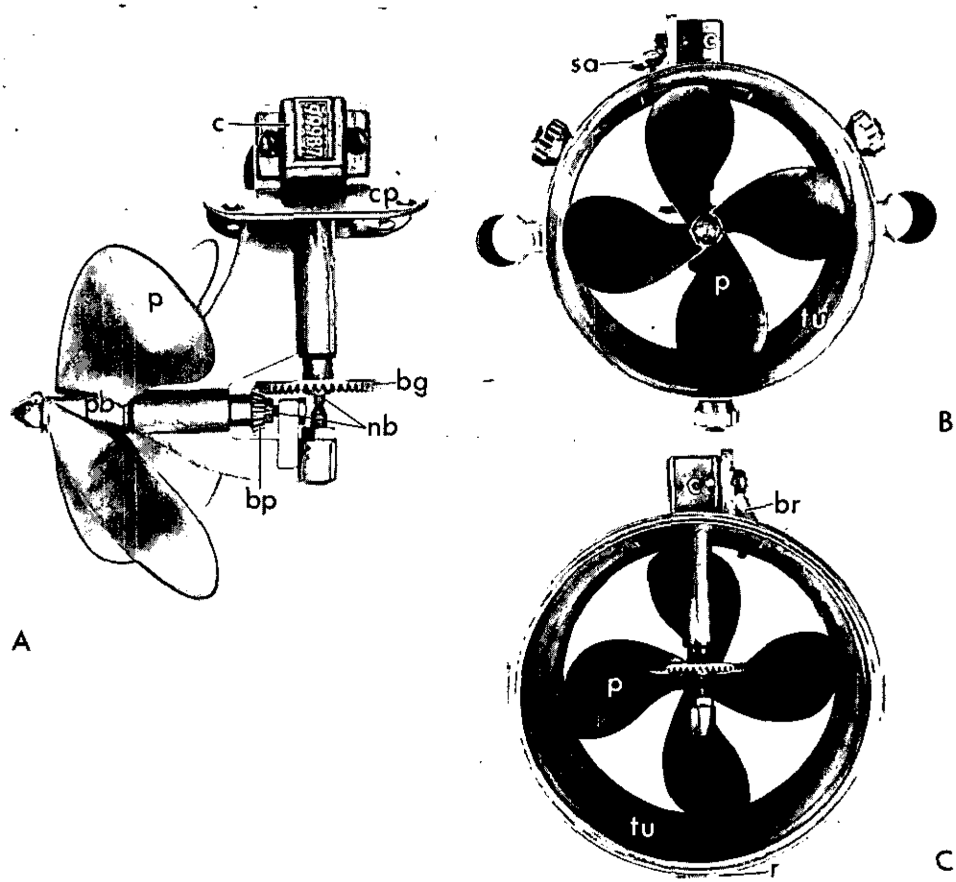

Fig. 6.—Flowmeter. (*A*) The flowmeter withdrawn from its housing (lateral view); (*B*) the flowmeter in situ (anterior view); (*C*) the flowmeter in situ (posterior view).
bg, bevel gear; bp, bevel piston; br, bracket; c, counter; cp, curved plate; nb, needle bearings; p, propeller; pb, propeller boss; r, rail; sa, safety screw; tu, tube.

The entire flowmeter assembly is supported within the tube of the after section by a bracket welded to a $3\frac{1}{2}$-in. by $2\frac{1}{2}$-in. curved plate (see Fig. 6(*A*)) covering a window in the tube of the after section and screwed to it. The flowmeter minus the propeller, which can be attached and detached in position, is inserted and withdrawn through this window.

The laterally facing counter is mounted upon a sturdy bracket with lateral gusset (see Fig. 6(*C*)) welded to the curved plate covering the window in the barrel; it readily detaches from the bracket without disturbing the flowmeter. The counter

(Veeder–Root, Model E 129536) is reliable and apparently non-corrodable but needs careful maintenance. Salt water jams the unit in time, not by corrosion but by salt encrustation. Internal wear leads eventually to the formation of fine metal dust which can also cause jamming. If the unit is filled with oil, this dust will often mix with it to form a cloudy fluid obscuring the figures. Some oils react with seawater and create a similar problem; others react with the painted figures, which eventually lift off.

As a result, the counters used with Australian samplers are not oil-filled. They are allowed to fill with seawater during use, and after each tow are washed down with fresh water. After a cruise, the counter is removed, its baseplate lifted off, and the salt water and metal dust washed out with fresh water. This is all the maintenance

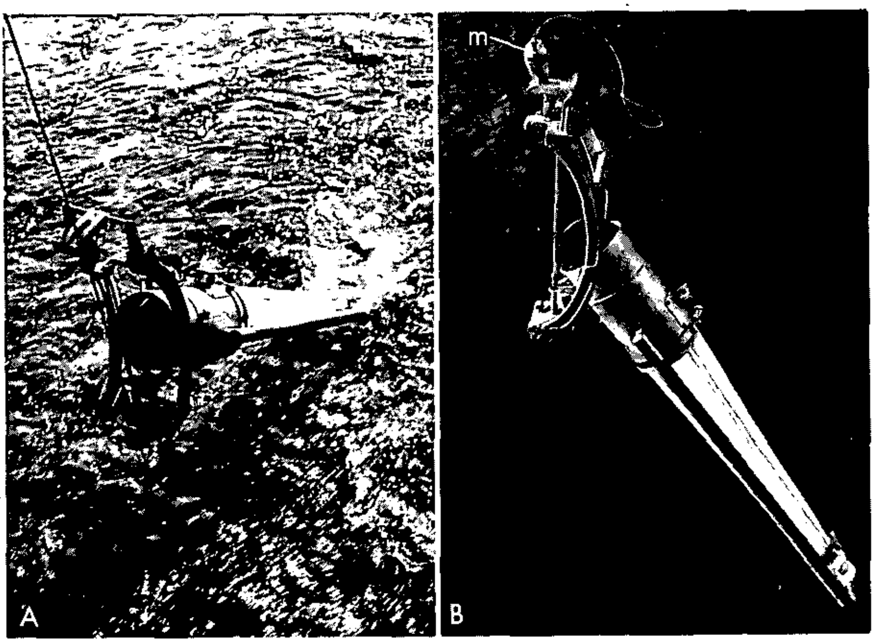

Fig. 7.—The sampler being lowered for (*A*) horizontal tow (*B*) oblique tow; m, messenger.

given in the field. As soon as a counter shows signs of "sticking", it is replaced by a new or reconditioned spare. Reconditioning consists of dismantling, thorough cleaning, and light lubrication. These procedures have eliminated counter troubles.

Depth Recorder (see Figs. 2(*A*) and 6(*C*)).—Beneath the tube of the after section is welded a 3-in. long rail of plated brass to which the depth recorder (Hamon, Tranter, and Heron 1963) may be attached.

Tailframe (see Fig. 2).—The tailframe consists of a pair of laterally placed wooden struts 30 in. long, joined at the after end by a cross piece. The struts fit into a tubular sleeve, 2 in. long, welded to the tube. The tailframe thus constructed, with depth recorder and net attached, streams horizontally at speeds greater than 2 kt. It is currently being replaced by a longer tailframe (36 in.) of tubular fibreglass with lateral aerofoils; this streams horizontally at speeds greater than 1 kt. The tailpiece could be made neutrally buoyant, but this is not recommended; it is safer for nets to hang downward at the end of a tow, to keep the catch in the cod end.

Net Assembly (see Fig. 2).—The nets used in the Australian sampler are 20 in. long. Their filtration coefficients under various conditions are discussed in a paper by Tranter and Heron (1965). They are currently being redesigned to improve filtration. At present the net is conical, constructed in three panels joined to each other by $\frac{3}{8}$-in. tapes and to $\frac{3}{4}$-in. webbing at either end.

The bucket is of Perspex approximately $2\frac{1}{2}$ in. in diameter and $3\frac{1}{2}$ in. long. It is in two parts, the after part screwing into the forward which is clamped to the cod end of the net. The forward part bears two lugs to which are hooked the springs from

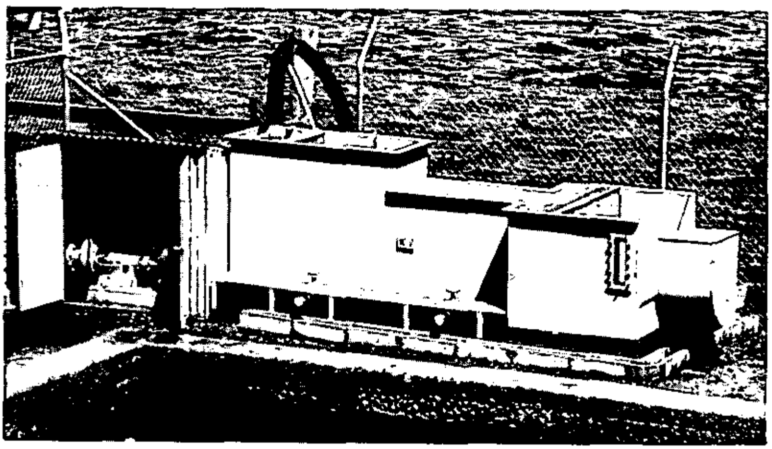

Fig. 8.—Calibration tank and pumphouse.

the after end of the tailframe, and it is left clamped to the net during a cruise. The after part of the bucket has a window of monel gauze $2\frac{3}{4}$ in. long by $\frac{1}{2}$ in. wide so that the catch may be removed without spilling. Though light, these buckets are sturdy and have remained undamaged during recent extensive field work. Being transparent, they have the advantage that the catch may be readily observed before preservation.

The net clamps are designed for quick attachment and release. They are provided with a large knurled knob and are screwed and unscrewed by hand.

The sampler completely assembled is shown in Figure 7.

III. Calibration Tank

The calibration tank (Fig. 8) was designed by Mr. K. M. Hart and Mr. R. F. Halliday of the Hydrodynamics Laboratory, University of Sydney, for calibrating Clarke–Bumpus flowmeters at velocities up to 5 kt. Their experience suggested that under normal towing conditions the free stream velocity would be reduced at the mouth of the flowmeter, due to flowmeter drag, and that the flow would expand, filling the entire space (Fig. 9(i)). Such a pattern would have been obtained by Yentsch and Duxbury (1956), who calibrated an American Clarke–Bumpus sampler in a flume where water could pass freely around and through the meter at velocities less than 2 kt.

By channelling the entire water supply into the flowmeter, velocities can be greatly increased. However, mounting of the flowmeter in a simple partition would

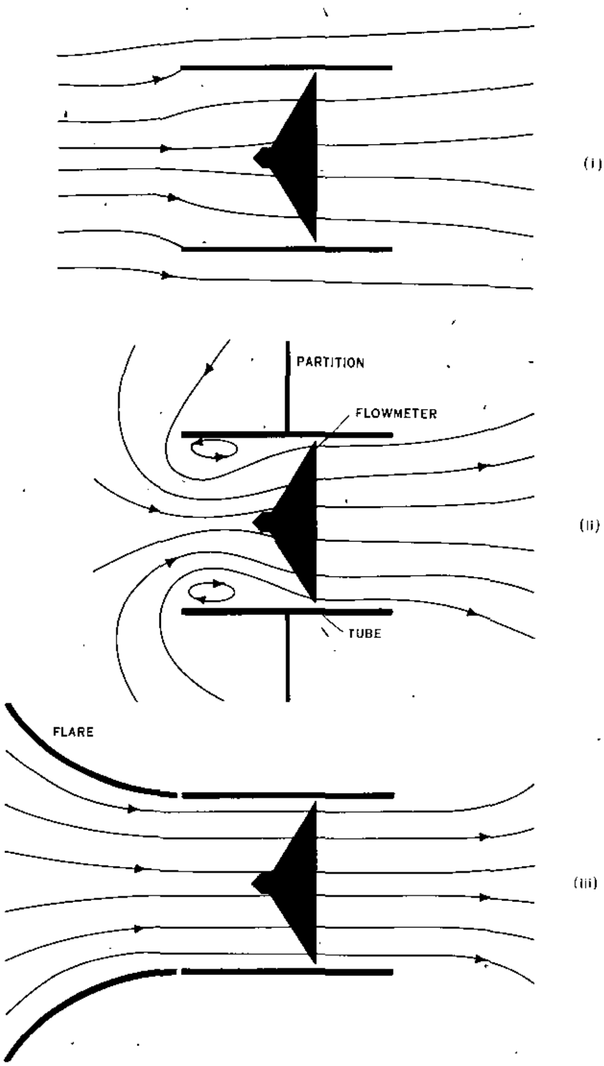

Fig. 9.—Probable streamline patterns through the flowmeter. (i) Normal plankton tow (natural flow); (ii) flowmeter mounted in a simple partition (undisciplined flow); (iii) flowmeter mounted in a flared partition (flow straight and parallel).

destroy the natural flow pattern. The streamlines would contract from the walls toward the centre, and vortices and separation bubbles would tend to form inside the leading edge (Fig. 9(ii)).

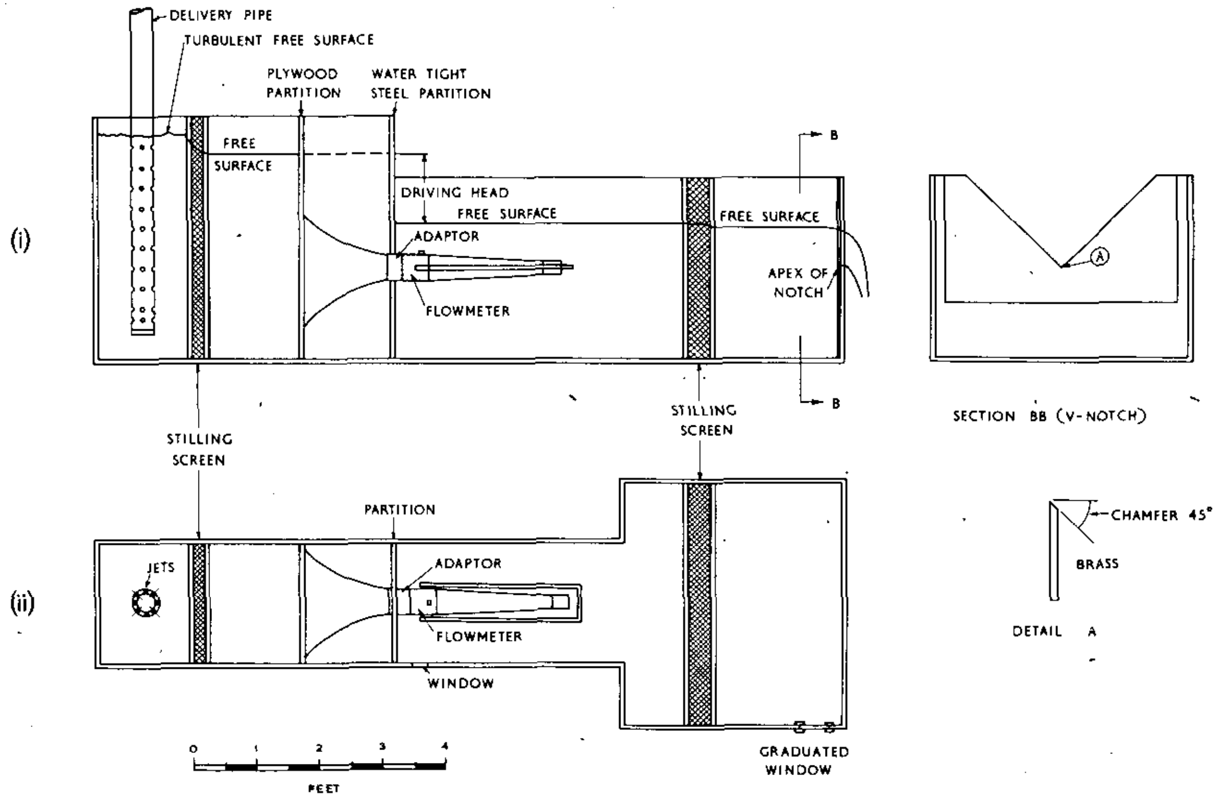

Fig. 10.—Constructional details of the calibration tank. (i) Elevation; (ii) plan. (Taken from blueprints prepared by the Hydrodynamics Laboratory, University of Sydney.)

These undesirable side effects can be avoided by leading the water to the flowmeter through a rounded flare so that the flow becomes straight and parallel (Fig. 9(iii)). This principle was adopted by Messrs. Hart and Halliday in their design. The system does not entirely simulate natural flow conditions through the flowmeter, but it is regarded as a satisfactory compromise.

The tank was made of $\frac{1}{4}$-in. mild steel, sprayed with zinc and painted with epoxy resin for protection against corrosion, and is sited just above high-water mark (see Fig. 8). A 4-in. centrifugal pump driven by a 5 hp motor draws water from a footvalve, just below low-water mark, through a hose of 4-in. heavy armoured rubber. A gatevalve on the discharge side of the pump controls the flow to a 4-in. galvanized steel pipe suspended vertically within one end of the tank. This pipe is sealed off at the bottom and is perforated with holes so that water enters the tank evenly and fairly quietly.

The design of the calibration tank is shown in Figure 10. The water issues through a stilling screen of coarse ($\frac{3}{4}$-in.) metal aggregate into a well-rounded flare of spun copper, 18 in. long. This is supported at the wider end upon a vertical sheet of $\frac{1}{2}$-in. marine plywood, and at the narrower end upon a permanent vertical steel partition, structurally part of the tank and completely watertight. Here there is an adaptor to receive the flowmeter. Originally, the flowmeter was inserted forward of the partition, but this proved an awkward procedure, particularly with closing samplers. The meter is now inserted behind the partition where the wall of the tank is lower, the counter being read through a small Perspex window.

The discharge from the flowmeter enters a wider (4 ft) part of the tank and slows down. Another stilling screen at this point calms the water so that its height can be measured through a second window near the exit. The water leaves the tank by a 90° V-notch cut in a plate of $\frac{1}{4}$-in. brass attached to the end of the tank, the notch controlling the discharge so that the head of water just upstream measures flow through the tank. The window has a scale engraved in inches and tenths, the zero coinciding with the apex of the V-notch. The error involved in measuring flow by this method is approximately $1 \cdot 5\%$.

The calibration procedure is as follows. The pump is started and the tank filled to the apex of the V-notch. The sampler is inserted, with or without net, and the flow is adjusted at the gatevalve to the required velocity. When the flow is steady, readings are taken of the head and the flowmeter rate, the latter being timed by stop-watch. The gatevalve is adjusted to the next rate of flow, and the procedure repeated. The flow in m^3/min is obtained from standard tables of head-flow for a 90° V-notch. Flowmeter rate in counts/min is divided by flow in m^3/min to give calibration values in counts/m^3.

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