COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 82

THE CSIRO SATELLITE-TRACKED "TORPEDO" BUOY

By G. R. Cresswell*, G. T. Richardson*, J. E. Wood*, and R. Watts†

*CSIRO Division of Fisheries and Oceanography, P.O. Box 21, Cronulla NSW 2230
†St Taw Plastics Pty Ltd, 60 Stanley Street, Peakhurst NSW 2210

P.O. Box 21
Cronulla, N.S.W., 2230
1978

ISBN 0 643 02050 0

Printed by CSIRO, Melbourne

79.256-600

THE CSIRO SATELLITE-TRACKED "TORPEDO" BUOY

G.R. Cresswell, G.T. Richardson*, J.E. Wood* and R. Watts*†

*CSIRO Division of Fisheries and Oceanography, P.O. Box 21, Cronulla NSW 2230
†St Taw Plastics Pty Ltd, 60 Stanley Street, Peakhurst NSW 2210

Abstract—A relatively light (56 kg) buoy having low wind, wave and current drag is described. The buoy transmitter battery is charged by a solar panel and lifetimes exceeding one year have been obtained. The buoy has a parachute drogue.

INTRODUCTION

CSIRO has participated in satellite-tracked buoy experiments since 1972 when the French Centre National d'Etudes Spatiales (CNES) kindly made several "EOLE" satellite transponders available. The buoys developed for the "EOLE" experiments (Cresswell 1973, 1976) were PVC/fibreglass spars which were 5 m long, primarily because of the lengths of the transponder, sensor circuits and battery packs.

When the NASA weather satellite "NIMBUS-6" was launched in 1975 a new series of 12 spar buoys was constructed for surface current measurements in the eastern Indian Ocean. With a view to obtaining long "electronic" lifetimes a solar powering system was developed. Also, a change was made from the earlier "window shade" drogues to parachute drogues. Some conflict of opinion seems to exist as to the relative merits of these (Vachon 1973; Kirwan *et al.* 1975); we selected the parachute drogues because they took the least time to prepare.

At the conclusion of the Indian Ocean work in 1976 several factors combined to suggest that a new type of buoy hull be tried for future experiments. These were:

- almost 2 m of the spar buoys projected above the sea surface to constitute unwanted windage
- the 3 m of spar beneath the sea surface constituted an unwanted drogue
- sub-surface floats for current meter moorings (Boland *et al.* 1975) had been observed to provide very low wave and current drag
- the electronics components and the battery — the latter as a result of the solar panel — had greatly decreased in size from the "EOLE" days
- PVC and fibreglass had greatly increased in price
- a buoy which could easily be moved by two people — or by one with difficulty — was desired.

The result is the "torpedo" buoy hull which is the main topic of this report. The first of these was released into the Tasman Sea in November 1976 and since then 4 more have been used, along with 8 spar buoys, primarily to study East Australian Current eddies.

THE HULL

The hull (Fig. 1) is fabricated from PVC sheet which is shaped and welded and then reinforced with fibreglass. It consists of a cylinder with a conical bow section, a truncated conical stern, and a vertical gussetted cylinder to accommodate the antenna. Beneath the stern is a small skeg, while further forward is a 19 mm "U" bolt firmly built into the buoy.

When delivered from the factory the buoy is already plastic foamed as shown in Fig. 1 and the solar panel is fitted. The fitting of the electronics is done through the stern access port. The buoy telemetry transmitter (BTT) and sensor circuits are inserted into the central instrument tube and then sealed. The thermistor is inserted from the buoy interior into a tube in the skeg and held in position by pouring in suitable molten wax which subsequently sets. The combined battery and regulator box is held in position by bolts. Several bolts also secure the antenna. After laboratory testing the stern section is plastic foamed through the access port. The stern plate is bolted on and the buoy is returned to the factory to have this plate and the exposed bolts covered with fibreglass. The mass of the assembled buoy hull is 56 kg.

ELECTRONICS

(a) Power Supply

The buoy telemetry transmitter (BTT) made by American Electronics Laboratories (AEL) is powered by a 12 V, 4.5 Ah sealed lead-acid battery (Sonneschein 6Fx35), which is charged by a 16 V, 650 mA solar panel (Elcoma BPX47A). The output of the solar panel is controlled by a shunt regulator (Fig. 2) to prevent the specified float charge voltage of the battery from being exceeded. The reverse bias breakdown of the emitter-base junction of Q1 is used as the reference voltage because the very low knee-current allows the power consumption of the divider network R1, RV1, R2, R11, TH1 to be reduced to a negligible level. Thermistor TH1 provides a negative temperature coefficient to match the specified temperature coefficient of the float charge voltage of the battery.

If the output of the solar cell is greater than that required by the load and battery, Q1 conducts turning on transistors Q2, Q3, Q4, and Q5, reducing the output voltage of the solar cell to that required to maintain the battery at the specified float voltage. Diode D1 prevents the battery from discharging through the solar cell. The shunt current through R9 and R10 is monitored by measuring the voltage at the junction of R10 and the collector of Q5.

The average continuous power requirement of the electronics system is 0.3 W. A fully charged battery will thus provide one week of operation without output from the solar panel.

The peak output of the solar panel is 7.5 W with the sun directly overhead. Under cloudless conditions, at low latitudes the 24 hour average is approximately one quarter of this value, i.e. approximately six times the continuous power requirements. This leaves a considerable margin for operation under poor weather conditions or at higher latitudes. It is not essential that the buoys operate continuously as the system is capable of recovering from a discharged battery. The satellite is sun-synchronous, so that it is more likely that sufficient average power will be available while the satellite is within range than at other times.

As an indication of the capability of the power supply system, buoy 0107 was released in April 1978 at 50°S and operated throughout the winter months at that latitude.

(b) Sensor Interface Board

The sensor interface board, Fig. 3, contains two bridge networks and amplifiers (A1 and A2) and a sample-and-hold network, a voltage follower (A3), a regulated bridge power supply and control logic. One bridge network (A1) is used with a thermister temperature sensor mounted in the skeg to measure sea surface temperature, while the other may be used with either a thermister or a potentiometer pressure transducer.

Each of the amplifiers consists of an operational transconductance amplifier (CA3080) with a bias current of 5 microamperes and a CMOS inverter ($\frac{1}{3}$ CD4007) as the output stage. The sensor bridges and amplifiers are powered only during the one second immediately preceding the transmission period to avoid RF coupling problems and reduce power consumption. The LM723 regulator provides a regulated 3.6 V supply for the sensor bridges during this period.

During transmission, switch S1 ($\frac{1}{3}$ CD4016) is closed and a voltage proportional to the battery voltage at that time is stored on C1. Sixty two seconds later during the next measuring interval S2 is closed, the interface electronics are activated and the stored on-load voltage is applied to the BTT analogue input for conversion to a digital word.

Off-load voltage and the shunt voltage from the regulator are connected to their respective BTT inputs via a scaling resistor and analogue switch ($\frac{1}{4}$ CD4016) during the measurement period.

(c) BTT Modifications

Because the sensor amplifiers were severely affected by RF coupling during the transmit pulse, the BTT was modified so that the sensor amplifiers are turned on and the A/D conversions performed by the BTT during the second immediately preceding the transmission period. The digital output of the A/D convertor is shifted into the output data shift register of the BTT, while the conversion takes place. In the following second data is shifted out to the demodulator during transmission in the same way that parallel digital data was handled before the modification was carried out.

(d) Temperature Bridge Calculations and Calibration

The resistance values for the thermistor bridge are calculated to give a minimum deviation from a linear characteristic over the desired temperature range (Beakley 1951).

Each thermistor's resistance is measured at several temperatures and least squares fitted to the equation

$$R(T) = Ae^{(B/T)}$$

where A,B are constants for the particular thermistor

T is the absolute temperature
R(T) is the thermistor resistance.

Then for bridge 1, Fig. 3

$$R3 = \frac{B-2T_o}{B+2T_o} R(T_o)$$

where T_o is the midscale temperature.

Then

$$R4 = \frac{R1\{V_H(R3+R(T_H))-V_L(R3+R(T_L))\}}{V_E(R(T_L)+R(T_H))}$$

and

$$\frac{1}{R2} = \frac{R(T_H)}{R3.R1} - \frac{1}{R4} + \frac{V_L(R3+R(T_L))}{V_E.R4.R3}$$

where

T_H is full-scale temperature

T_L is zero-scale temperature

V_H is output voltage at full-scale temperature

V_L is output voltage at zero-scale temperature

V_E is bridge excitation voltage

R1 may be chosen.

We use an STC F14D thermistor with a nominal resistance of 10 KΩ at 20°C. We choose $T_H = 35°C$, $T_L = 5°C$, $V_H = 10$ V, $V_L = 0$, $V_E = 3.6$ V, $R_1 = 10$ KΩ. Typical values for R_2, R_3, and R_4 are 4.3 KΩ, 8 KΩ, and 27 KΩ respectively.

After assembly of the sensor and BTT an overall system calibration is performed using the digital readout of a BTT test system. This eliminates the small error associated with the thermistor self-heating time constant if the calibration is done statically.

(e) Assembly and Testing

When the above construction, testing, modification and calibration have been carried out, a complete electronics system consisting of BTT, interface circuits, sensors, regulator and battery, and if available solar panel and antenna, is assembled and run on test for a period of at least one month. During this time frequent checks are made on the performance of the system and any failures or changes are rectified. The system is not installed in a buoy hull until at least one month trouble free operation has been achieved.

THE DROGUE AND RIGGING

The arrangement of the drogue and rigging is given in Fig. 4. Taking the components in order from the inbuilt buoy attachment point, a 19 mm galvanised "D" shackle is connected to 3 m of 12 mm galvanised ballast chain (1). Spliced into the last link of the chain is 20 m of 14 mm polyethylene mono rope (2). To the lower spliced end of this main tether rope is connected a stainless steel swivel (3) and a 150 mm diameter ring of 12 mm stainless steel (4). Spliced directly onto this ring is a second tether of 10 m of 12 mm polyethelene mono rope (5) spliced directly onto a 5 kg lead weight or old chain (6). Another swivel (7) is secured to the stainless steel ring and is connected to the drogue tether, this being 14 mm polyethylene mono rope 1 m in length (8). Attached to the drogue tether is a spreader frame (9) which is a 460 mm pyramid constructed from 9.5 mm diameter mild steel rod with 12 mm galvanised "D" shackles in the four base corners to accept the shroud lines of the parachute. The parachute drogue is a disposal RAAF personnel parachute, 4.8 m in diameter. The 24 shrouds are divided into four groups, spliced around nylon thimbles. All splices use nylon thimbles secured with nylon twine and encapsulated in "Araldite". All screwed fittings are welded shut. The component masses are:

ballast chain	(1)	- 11 kg
weight	(6)	- 5 kg
spreader frame	(9)	- 4 kg.

PERFORMANCE

From the electronics standpoint the buoys both in the Indian Ocean and in the Tasman Sea have been very successful (see for example Cresswell and Vaudrey 1977; Cresswell and Wood 1977). In the Indian Ocean an average lifetime of 210 days was obtained with 4 of the 12 buoys reaching or exceeding a lifetime of 1 year. The average lifetime would have been longer but for buoys which prematurely ran aground, although one of these continued to operate on the lonely Great Australian Bight beach for eight months. Another grounded buoy was recovered and taken to the Tasman Sea and re-released there; its life now exceeds 2 years.

In the Tasman Sea 13 buoys — spars and torpedos — have been released since November 1976. Of the spars, one has failed due to a battery fault and one ran aground. A torpedo which apparently failed after 6 months was recovered aground and found to have parted from the ballast chain, probably due to the 12 mm shackle wearing through — 19 mm shackles were introduced later. The loss of the ballast chain meant that the buoy floated on its side thereby adversely affecting its ability to recharge or transmit. Even so, it did succeed in making contact with NIMBUS-6 every few weeks. The other 4 torpedos in the Tasman Sea continue to operate with 2 having exceeded a lifetime of 1 year; 3 of the spars have also exceeded a lifetime of 1 year.

As far as the rigging is concerned it is not possible to say with certainty how long this will last. However, the buoys that have been recovered revealed the tether line to have chafed away where it is spliced into the bottom of the ballast chain. Future tether lines will be constructed from 5 mm stainless steel cable. The problem can be partially solved by attaching a load cell to the bottom of the buoy in the manner of Richardson *et al.* (1977).

In 1977 one of the uses of the buoys was to monitor the position of an eddy, labelled B, to enable its evolution with time to be followed by research vessel surveys. The tracks of some of the buoys in the eddy B vicinity throughout 1977 are shown in Fig. 5. Further information on buoy tracks, speeds, and measured temperatures can be obtained from a series of data reports (e.g. Cresswell and Wood 1977).

Acknowledgements

We thank all those people who have assembled, released, and recovered the buoys as well as the staff at NASA and CNES.

REFERENCES

Beakley, W.A. (1951). The design of thermistor thermometers with linear calibration. *J. Sci. Instrum.* 28, 176-9.

Boland, F., Cresswell, G.R., and Wood, J. (1975). The CSIRO continental shelf mooring system for current meters. CSIRO Aust. Div. Fish. Oceanogr. Rep. 62.

Cresswell, G.R. (1973). The French-Australian satellite-buoy experiment. *Aust. Met. Mag.* 21, 1-17.

Cresswell, G.R. (1976). A drifting buoy tracked by satellite in the Tasman Sea. *Aust. J. Mar. Freshwater Res.* 27, 251-62.

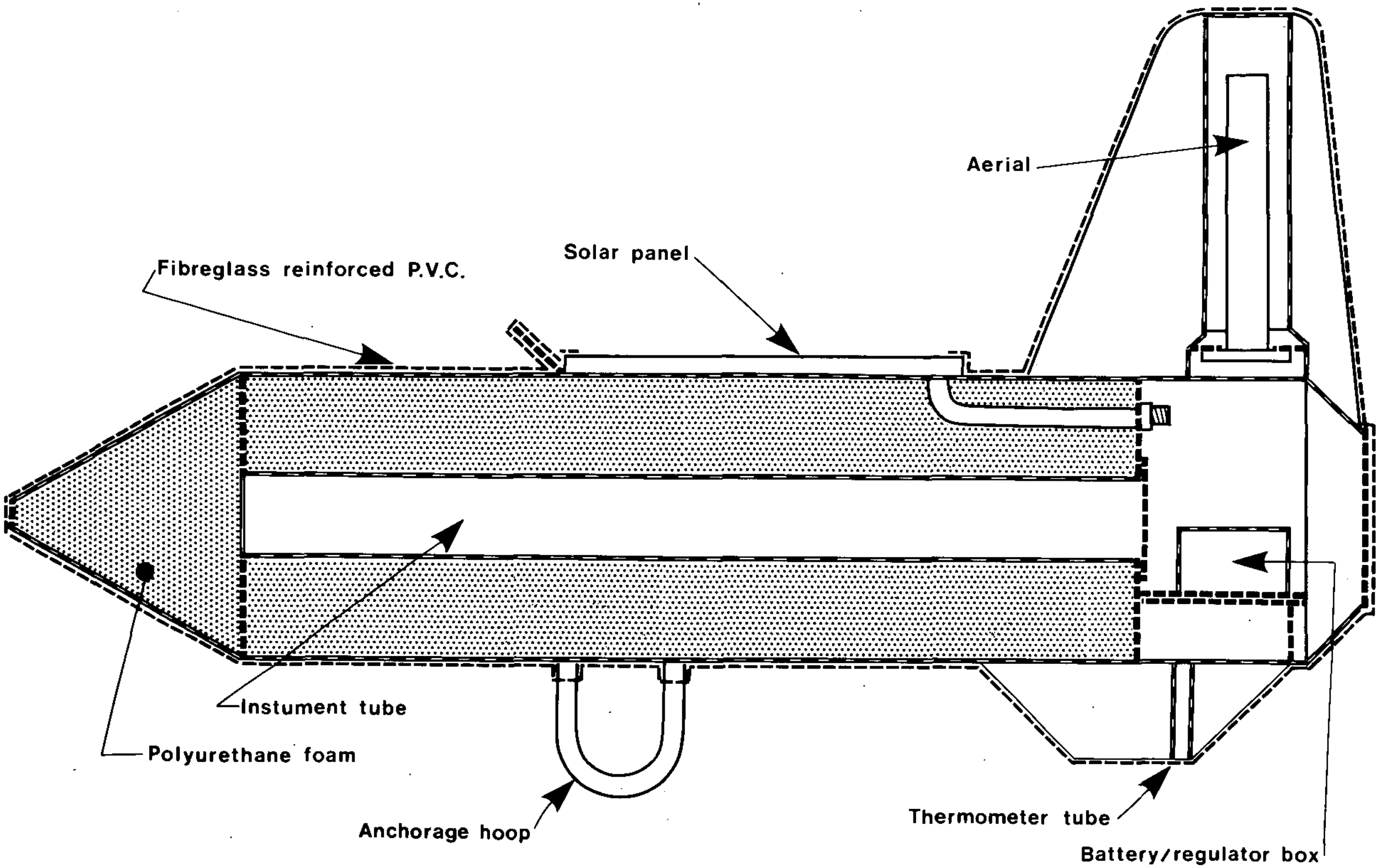
Cresswell, G.R., and Vaudrey, D.J. (1977). Satellite-tracked buoy data report I: Western Australian releases 1975 and 1976. CSIRO Aust. Div. Fish. Oceanogr. Rep. 86.

Cresswell, G.R., and Wood, J.E. Satellite-tracked buoy data report II: Tasman Sea releases November 1976-July 1977. CSIRO Aust. Div. Fish. Oceanogr. Rep. 91.

Kirwan, A.D., McNally, G., Chang, M.-S., and Molinari, R. (1975). The effect of wind and surface currents on drifters. *J. Phys. Oceanogr.* 361-68.

Richardson, P.L., Cheney, R.E., and Mantini, L.A. (1977). Tracking a Gulf Stream ring with a free drifting surface buoy. *J. Phys. Oceanogr.* 7, 580-90.

Vachon, W.A. (1973). Scale model testing of drogues for free drifting buoys. Technical Report. (The Charles Stark Draper Laboratory Inc.: Cambridge, Mass.), 137 pp.



FREE FLOATING “TORPEDO” BUOY

Fig. 1. The arrangement of the buoy hull.

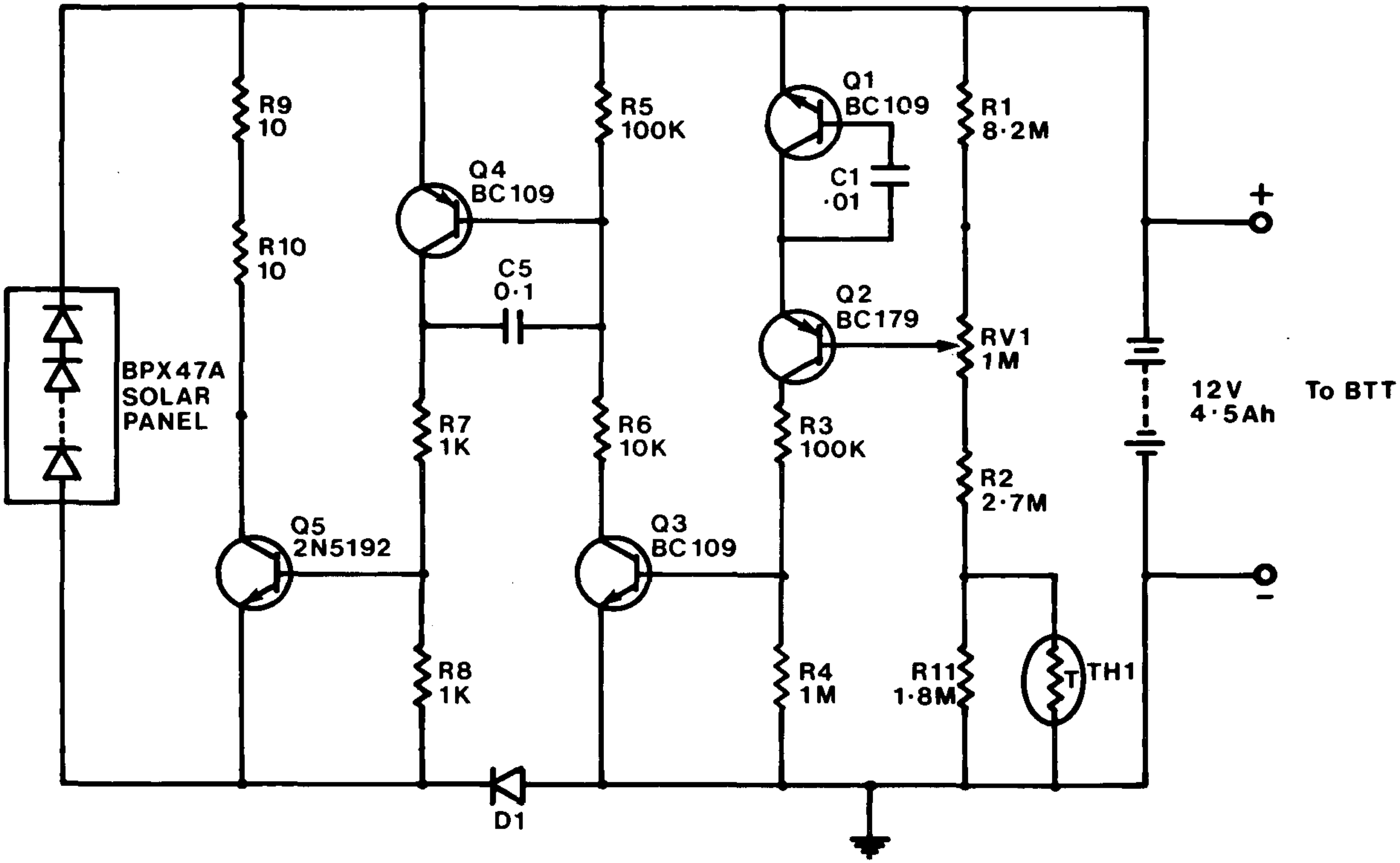


Fig. 2. Power supply.

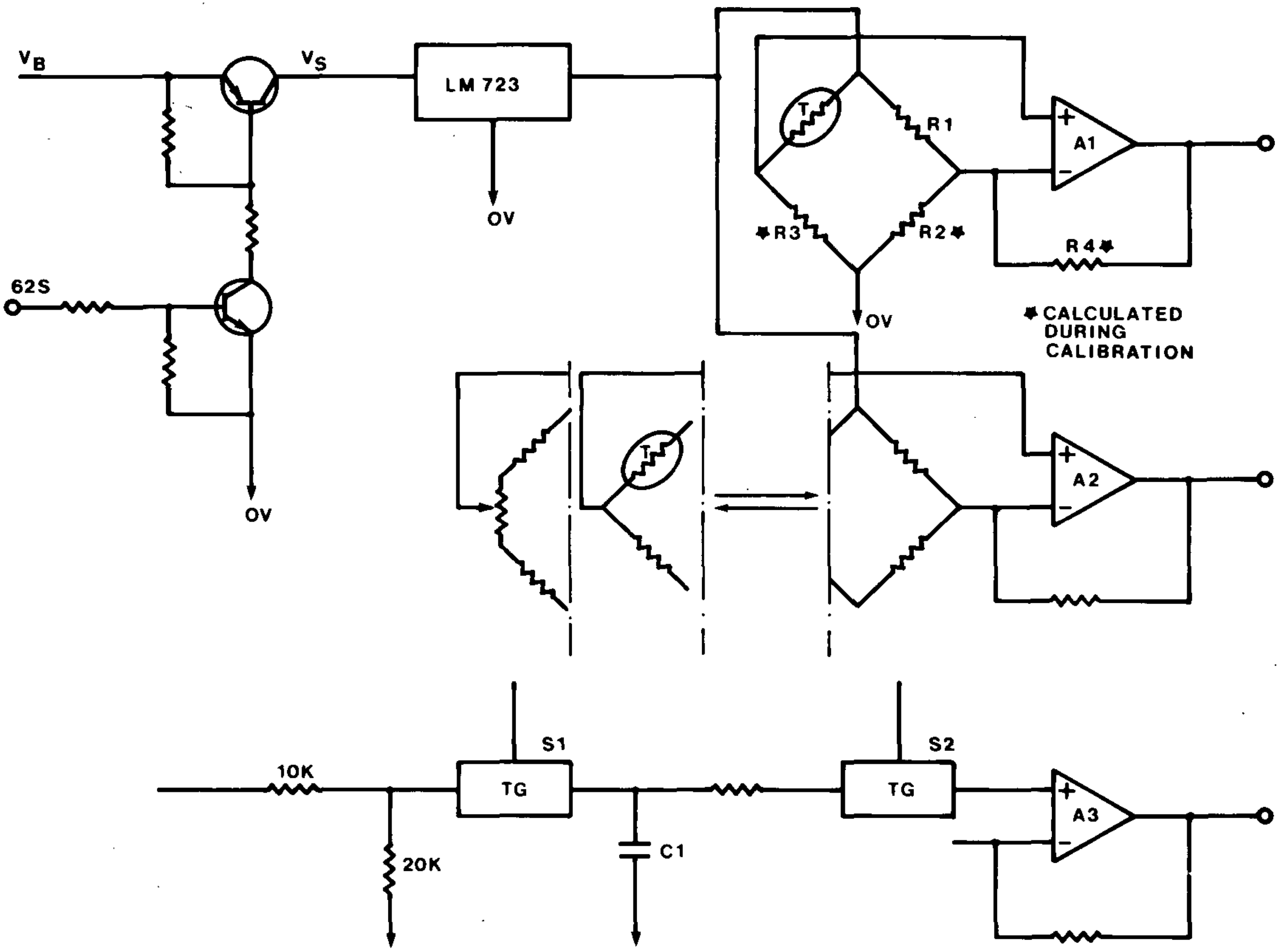
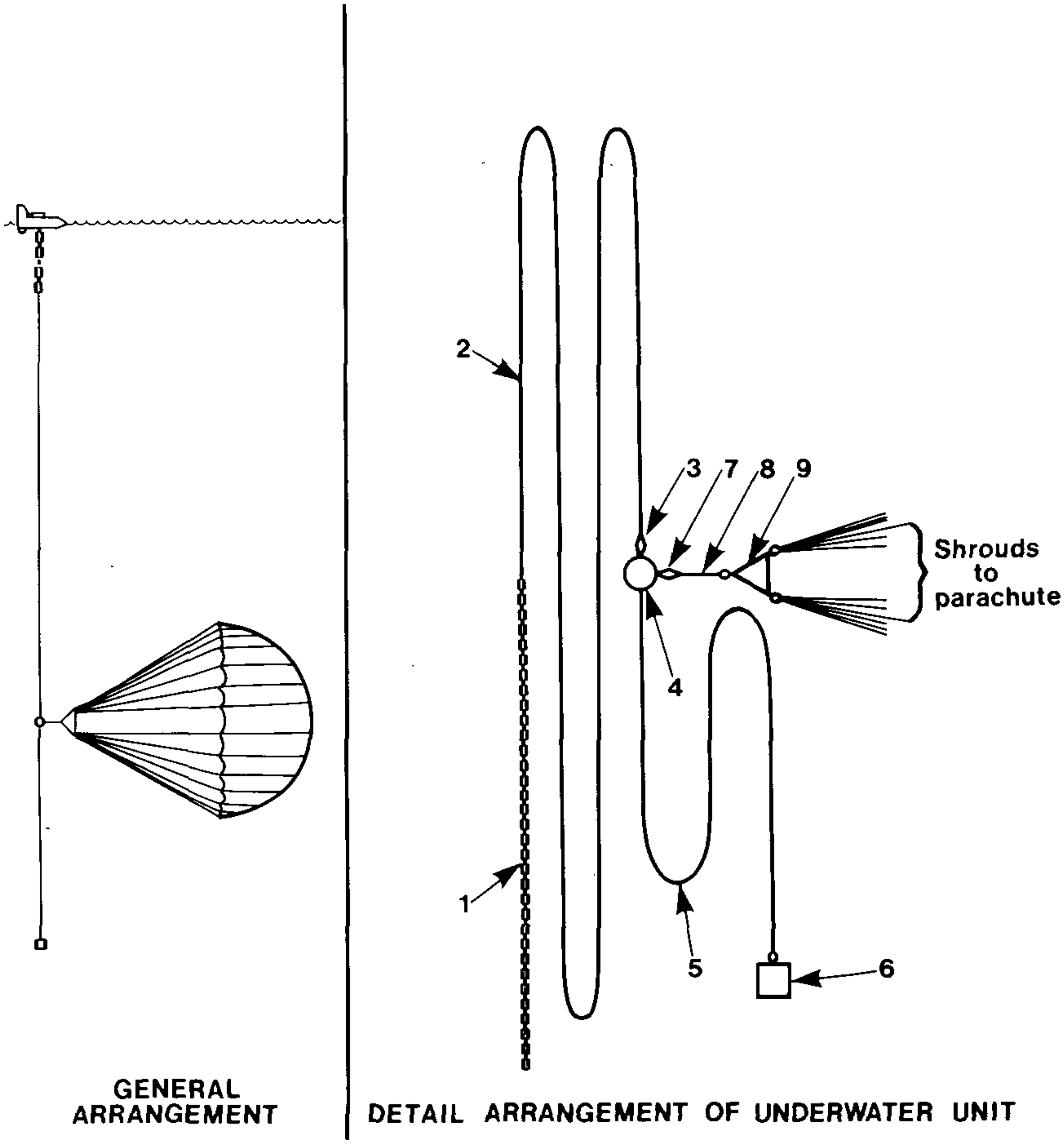


Fig. 3. Sensor interface circuit.


GENERAL ARRANGEMENT

DETAIL ARRANGEMENT OF UNDERWATER UNIT

Fig. 4. The drogue system. See text for explanation of numbering.

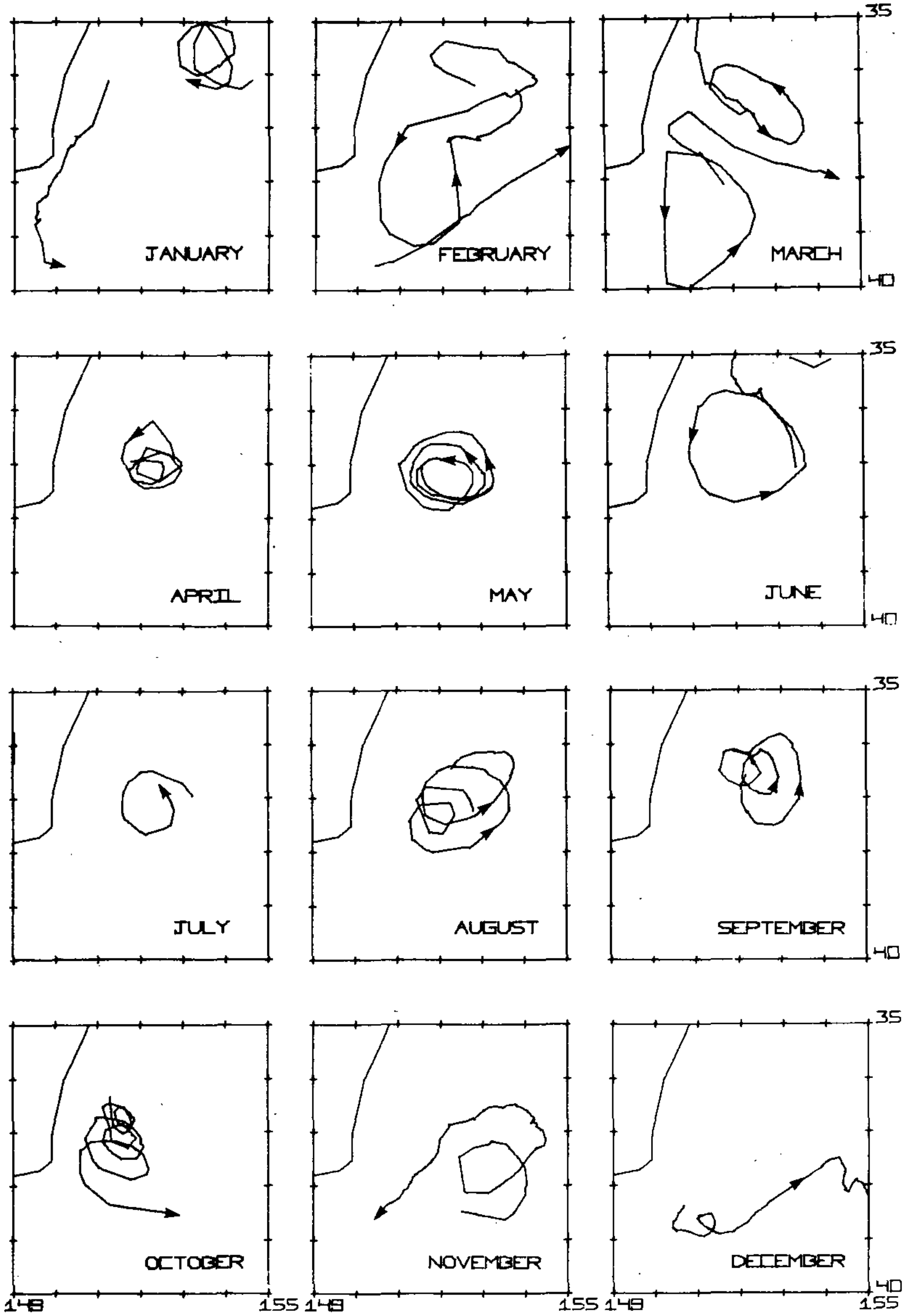


Fig. 5. The tracks of buoys in the eddy B vicinity during 1977.