I.O.S.

THE IOS ACOUSTIC COMMAND AND MONITORING SYSTEM
PART 3 – RELEASES, BEACONS AND TRANSPONDERS

G R J PHILLIPS

REPORT NO 96/3

1981

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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FOREWORD

The system has been developed as a service for U.K. oceanographic science to provide medium range (10 km maximum) remote control and real time monitoring of a wide variety of oceanic sampling equipment. It divides naturally into several categories which have been described in separate reports (some detailed to handbook level). These instruments have been developed to their present level over a number of years and may be subject to further revision and expansion. As and when these are significant, reports will be updated or extended. Many of the instruments have been designed to accommodate the addition of facilities. These facilities must only be added by an engineer fully conversant with the system.

Part One - Operating Principles and Practices.

Part Two - Shipborne System Mark III.

Part Three - Releases, Beacons and Transponders.

Future parts will cover

Some Recording Techniques,

Remote Monitoring Systems,

Sea Unit Hardware and some of its problems,

and the

Shipborne System Mark IV.

CONTENTS

Figures

THE IOS ACOUSTIC COMMAND AND MONITORING SYSTEM

Part III

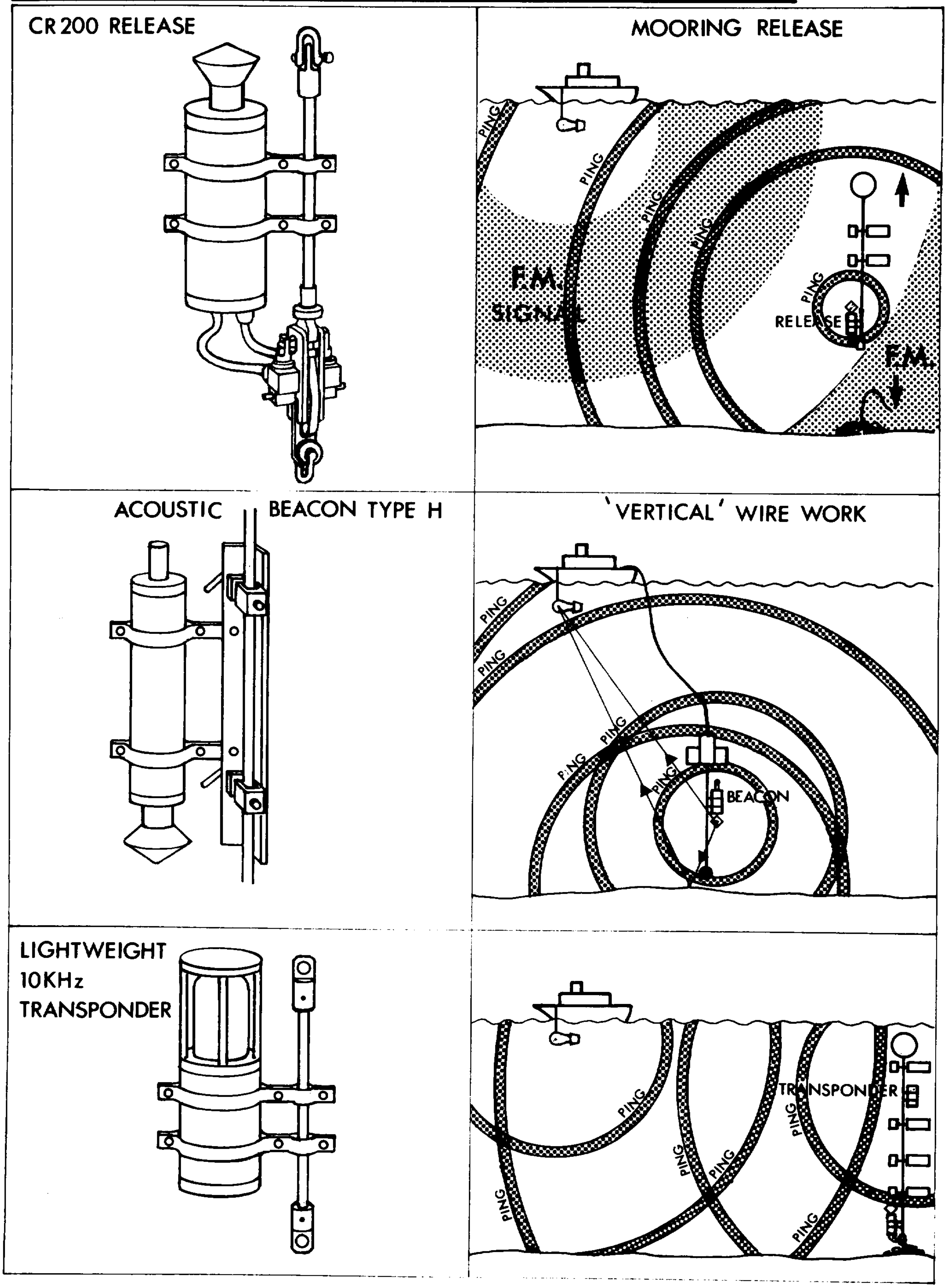
Releases, Beacons and Transponders

G.R.J. Phillips B.Sc.

SUMMARY

The general operating principles have been described in Part One of the series. Part Three describes the present generation (1980) of sea units used to apply these principles to practical scientific problems. The electronic techniques used for Acoustic Remote Control, Simple Remote Monitoring, and Location are explained by detailed description of the Command Release 200 Series, the Acoustic Beacon Type H, and the Lightweight 10 kHz Transponder. Some of the conditions of use of these instruments are discussed and some special versions in common use are described. Complex remote monitoring is not discussed as this will be covered in a separate report (Remote Monitoring Systems). A supplementary package (Part IIIa) describing alignment, maintenance, and faultfinding will be supplied to users of the system.

FIGURE 1. RELEASES BEACONS AND TRANSPONDERS



RELEASES, BEACONS AND TRANSPONDERS

1. INTRODUCTION

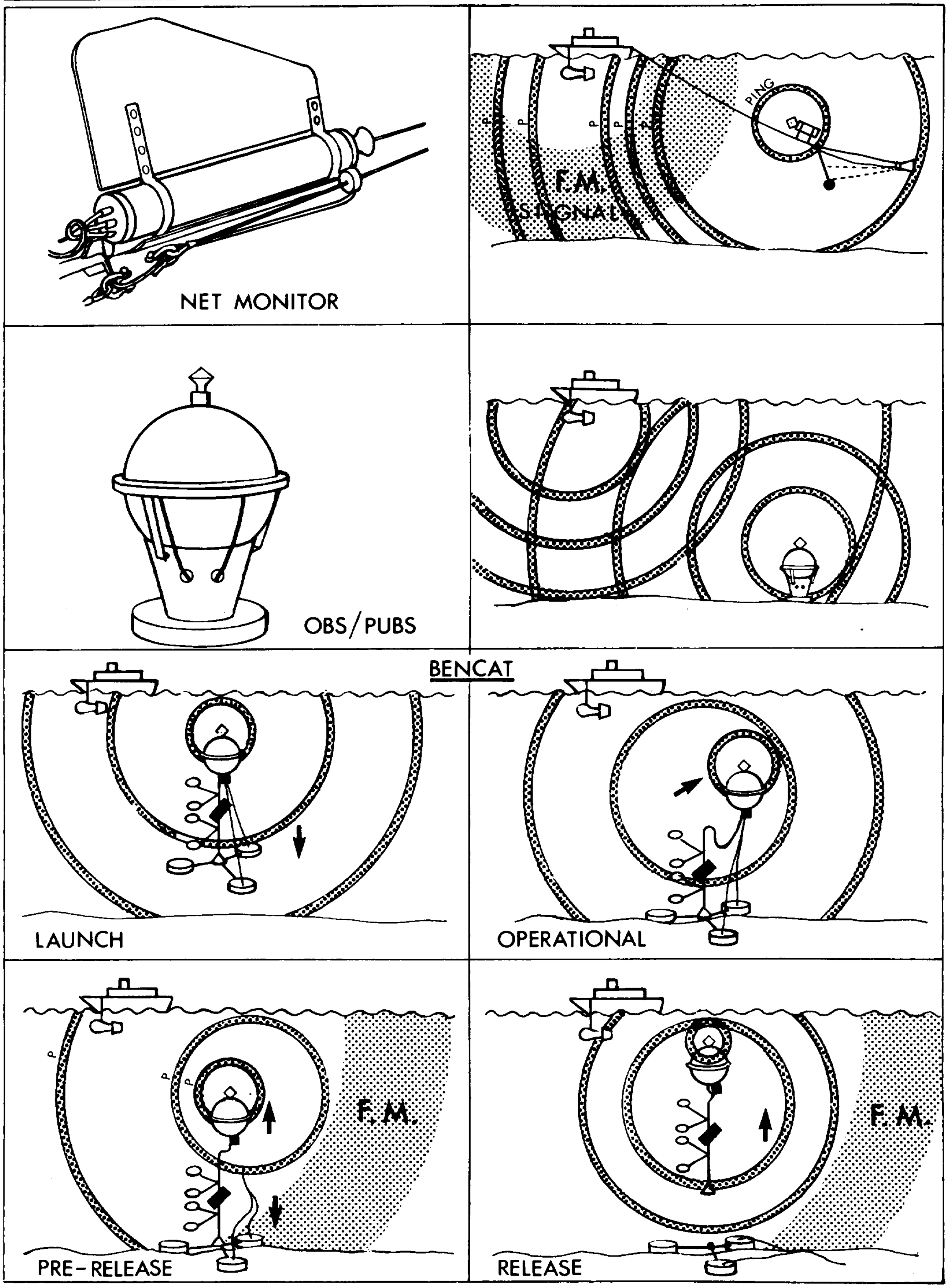
The original requirement of the acoustic command and monitoring system was to be reliably operable and monitorable to slant ranges of 10,000 metres at depths to 5,000 metres in the deep ocean. The present requirement has been slightly extended, depth capabilities of 6,000 metres and slant ranges of 15,000 metres are occasionally required, and reasonable performance is required on deep shelf (greater than 100 metres) deployments, but the system remains geared primarily to oceanic work.

Releases describes in detail the Command Release 200 design. The standard form was developed for the recovery of sub surface moored instrument systems; the electronics may be used with two types of acoustic transducer to service the differing requirements of deep (greater than 500 m) and shallow (less than 1000 m) systems; the standard form uses the 'flat discharge' voltage characteristic of high performance mercury batteries to stabilise micropower active filters to reliably operate for more than two years at one deployment.

Beacons describes in detail the Acoustic Beacon Type H design. The standard form was developed for the location of sub surface moored instrument systems and for real time monitoring of instrument systems deployed from but permanently attached to a ship; there are two versions to service these requirements, one using a 10 cm (4") pressure case for attached work, the other on a single 10 cm diameter circular card compatible with the CR200 release for moored work (there are two slightly different versions to match shallow or deep transducers); the electronics tolerates the large voltage variation of manganese alkaline batteries by using low power CMOS digital circuitry and will produce a precisely repeating one pulse per second continuously for more than 10 days. Using beacons is also discussed.

Transponders describes in detail the Lightweight 10 kHz Transponder design. The standard form was developed as a back up location device for the upper parts of long moorings; the electronics when powered with its advanced Lithium organic batteries will listen for two years and respond to interrogation signals repeating at two second intervals for 200 days; used as standard with a ceramic ring transducer ranges of 4,000 metres are obtainable at deployed depths of 200 metres. Using transponders is also discussed.

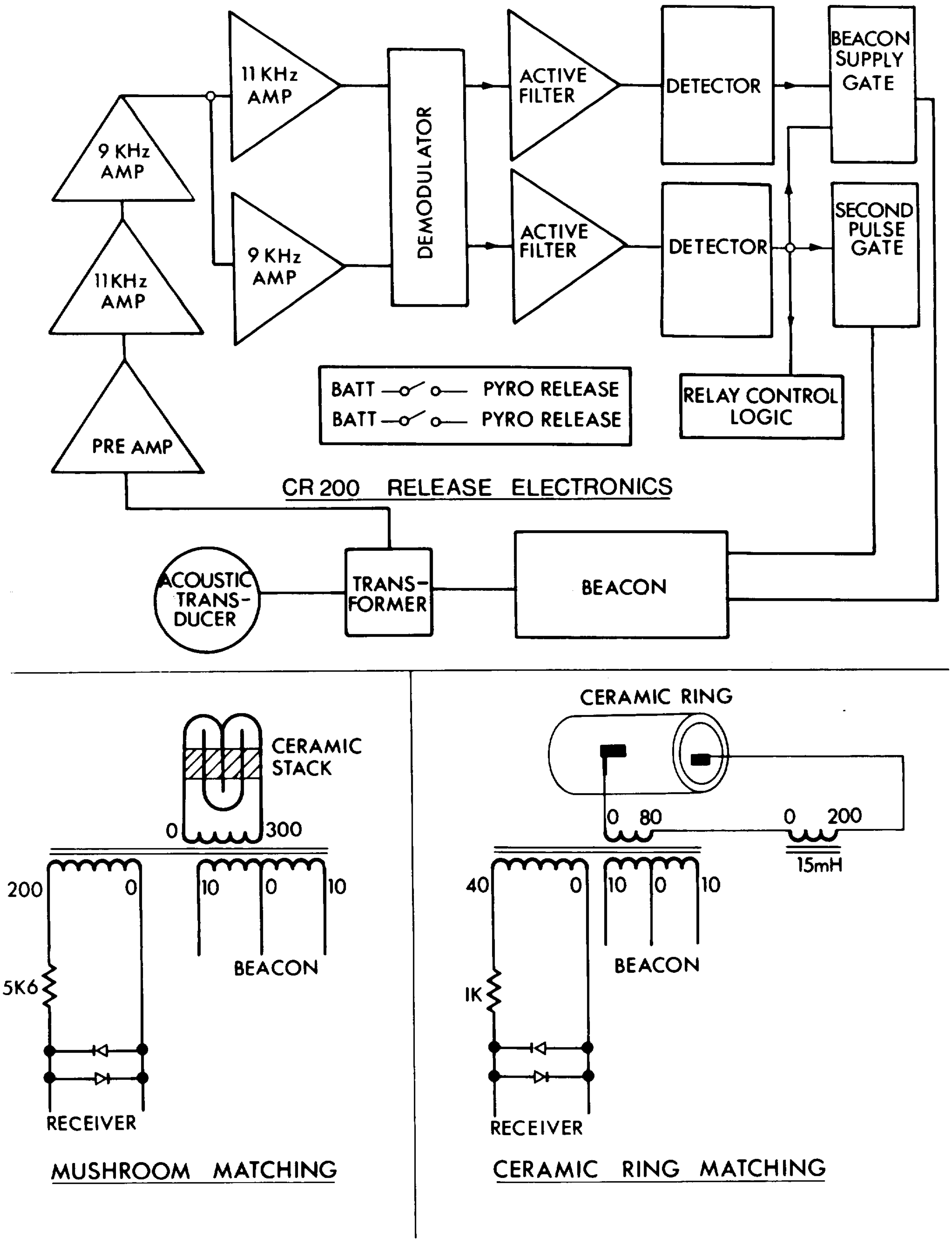
FIGURE 2. SOME SPECIAL APPLICATIONS



Special Versions describes in detail some of the major combinations and adaptations of the three basic instruments produced to service specialised applications. The section also discusses the principles used for simple alterations and changes of use.

Some of the Figures in addition to illustrating the text outline the recommended operational procedures.

Fig. 3 CR200 Release Electronics and Transducer Matching



2. RELEASES

2.1 General

The tasks required of the electronics are to recognise the command signals, to use them to perform functions, and to indicate the operational state of the unit. To carry out these tasks the signals must be extracted efficiently from the water; amplified to a level suitable for further manipulation; correctly identified in the presence of other signals; converted to a form suitable for control; used to control functions, to monitor the success of the control, and to convey this information to the controller. These tasks must be performed reliably for in excess of one year and by a unit as light and compact as reasonably possible.

2.2 The Receiver

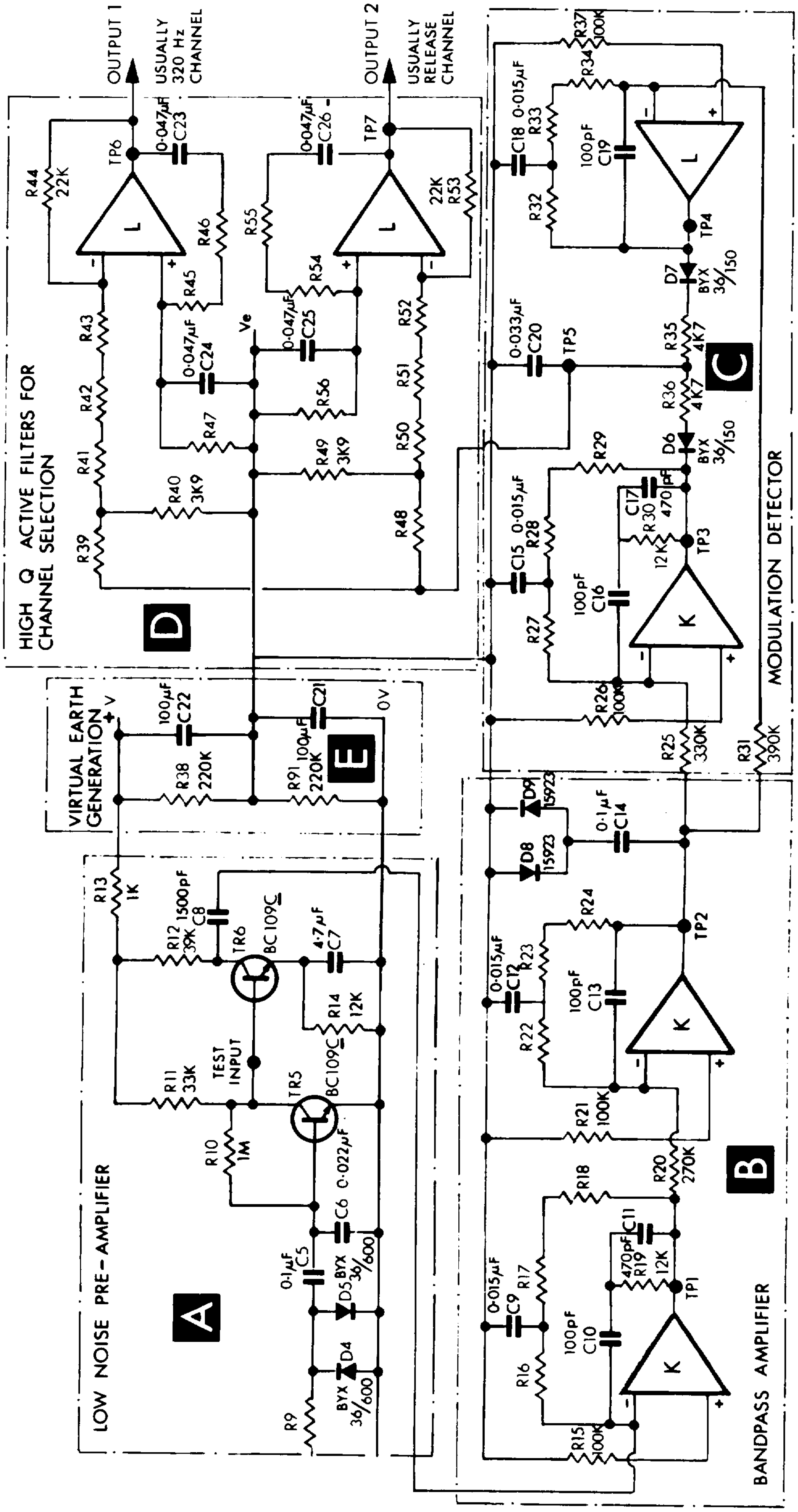
2.2.1 Acoustic vibrations in the water around the sea unit are converted to electric signals by an acousto-electric transducer. This transducer signal is matched to a low noise, high gain, and wideband preamplifier. The preamplifier output is amplified selectively (the 'bandpass' amplifier) and applied to the demodulator. The demodulator decodes the modulation frequency and offers this to the 'channel' filters (highly selective bandpass amplifiers). When a channel filter is stimulated in its pass band, its sympathetic oscillations are detected and used to trigger the functions required.

2.2.2 The matching stage between the transducer and the preamplifier must efficiently extract low power signals received without significantly impeding or being impeded by the transmission of the units high power reply signals. This stage differs for Mushroom and Ceramic Ring transducers.

The impedance of the mushroom at ten kilohertz is of the order of 2,000 ohms and is adequately matched using one transformer with three windings; high power output; low power input; and transducer. The impedance required at the low power winding is 6000 ohms and is made up of a pair of back to back diodes in series with a 5,600 ohm resistor. For very low signals this acts as a potential divider; the preamplifier is capacitively coupled to the junction where it sees one twelfth of the transducer output voltage. For high signal levels the diodes conduct, the winding impedance appearing to be that of the resistor.

The impedance of the ceramic ring at ten kilohertz is of the order of 500 ohms. This requires a series inductance as well as a transformer for an adequate match with the electronics. Three windings are again required on the transformer with an impedance of 2000 ohms in the low power winding. This is made up of a pair of

FIGURE 4. CR200 RECEIVER CIRCUIT



BRIDGED T FILTERS

R16 ≈ R17 + R18 ~ 8K2
R22 ≈ R23 + R24 ~ 10K
R27 ≈ R28 + R29 ~ 8K2
R32 ≈ R33 + R34 ~ 12K

WIEN BRIDGE FILTERS

R39 AND R48 - 150K, 180K, OR 220K.
R47 ≈ R45 + R46
R56 ≈ R54 + R55
R41 + R42 + R43 > 4K7 AND < 12K
R50 + R51 + R52 > 4K7 AND < 12K

diodes and a 1500 ohm series resistor for the same reasons as previously. This results in the same output voltage at the preamplifier input from a given sound pressure change with either transducer.

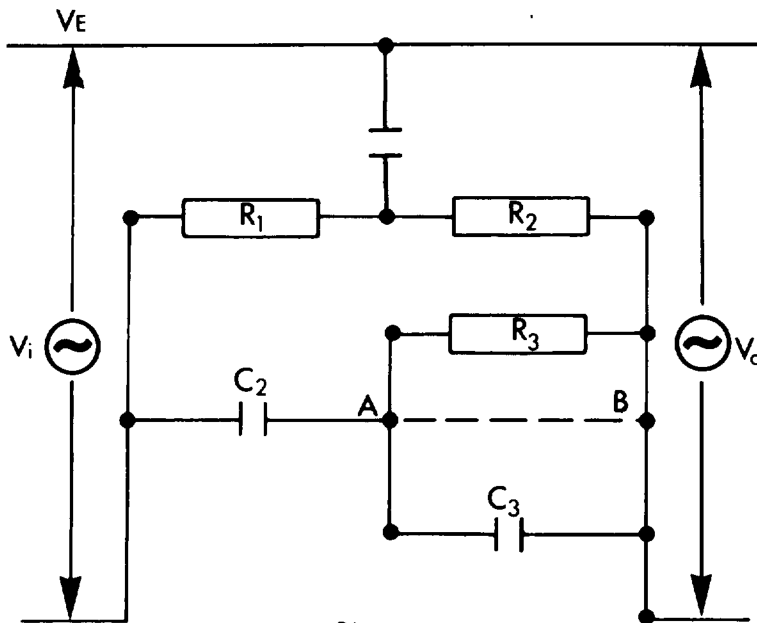
2.2.3 The preamplifier employs two low noise, high gain, signal transistors (type BC109C) DC coupled producing a voltage gain in excess of 2000. The emitter capacitor of the second stage biases off that stage for up to 50 milliseconds after a transmission pulse as it discharges. This does not significantly impede operation of the standard system. The collector of the second stage is capacitively coupled to the first stage of the bandpass filter.

2.2.4 The bandpass amplifier, modulation detector and 'channel' filters have been designed to meet one overriding criterion. The completed unit should reliably perform for in excess of one year in one deployment. Several techniques were investigated and of these the use of operational amplifiers in active filter configurations appeared the most suitable. However, these filters are voltage sensitive; voltage regulators commonly available consume greater power than the rest of the circuit; therefore for applications requiring long operational life, battery types with a stable output voltage are used - mercury, and more recently lithium, based cells. The CR200 sea unit now in standard production draws a maximum of 600 μA at 5.4V, with a typical 'quiet listening' current of 350 μA. With the standard 13 ampere hour mercury battery supply this gives a minimum duration of over two years and a possible maximum of four years. The restricting effects imposed by this performance are: the supply voltage must be stable to within plus or minus one quarter of a volt over the full duration; the performance of the filters differs from the theoretical; the variation in performance over the required 40^{o}C temperature range is significant. The split supply voltage these active filters require is produced by a simple voltage divider circuit (virtual earth generation) enabling a single supply to be used.

2.2.5 The purpose of the bandpass amplifier is to provide a signal of uniform amplitude from 9 to 11 kHz for driving the modulation detector while rejecting other frequencies. The technique chosen is that of stagger tuned active filters. Two circuits tuned to frequencies either side of the required passband centre frequency are connected in series. The frequency responses of the circuits combine to reduce their individual peak responses, enhance the frequency response of the band between the peaks, and to improve the rejection of frequencies outside this band. The filters in this case use single low power operational amplifiers with a 'Bridged Tee' feedback network. At frequencies below 10 kHz the 'ideal' circuit performs adequately but above 10 kHz compensation is used to reduce the

Fig. 5 The Basic Bridged T and Wien Bridge Circuits

BRIDGE T. NETWORK



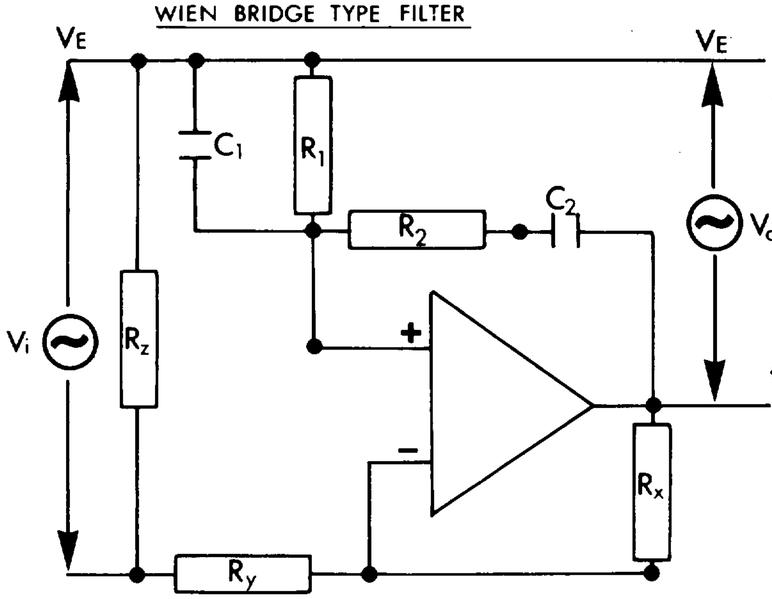
$$f_o = \frac{1}{2\Pi\sqrt{R_1 R_2 C_1 C_2}}$$

$$Q \alpha \sqrt{\frac{C_1}{C_2}}$$

R_3 AND C_3 REQUIRED AT FREQUENCIES ABOVE 10KHz

MIN. FEEDBACK ≅ MAX. GAIN AT f_o

WIEN BRIDGE TYPE FILTER



$$f_o = \frac{1}{2\Pi\sqrt{R_1\ C_1\ R_2 C_2}}$$

for oscillation :–

$$1 + \frac{R_x}{R_y + R_z} < 3$$

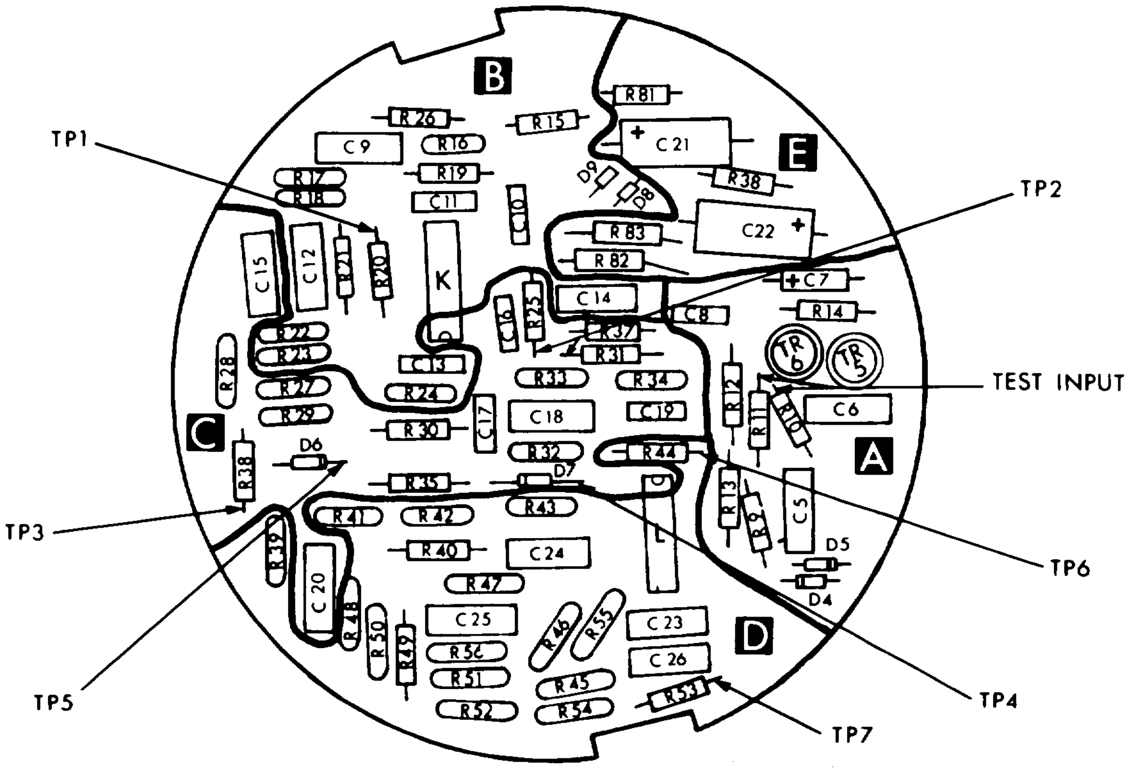
R_x AND R_y CONTROL THE GAIN AND THUS THE Q sharp low frequency cut off and hysteresis that becomes increasingly significant. To achieve the required passband of 9 to 11 kHz the first stage is tuned to approximately 10.6 kHz and the second stage to 9.4 kHz. To achieve the uniform amplitude required the second stage is A.C. coupled to back to back diodes referred to the 'virtual earth' midpoint voltage: this clips the second stage output to 1.0V peak to peak maximum. The two stages are D.C. coupled and weighted such that their overall voltage gain is about fifty when clipping over the full passband.

2.2.6 The modulation detector consists of two circuits driven in parallel and tuned to opposite ends of the passband whose outputs are summed in opposite senses which decodes the modulation frequency. The tuned circuits are again active filters using low power operational amplifiers with Bridged Tee feedback networks. Their centre frequencies are tuned to approximately 11.3 kHz and 8.7 kHz. They are driven such that a clipped output from the bandpass amplifier results in a peak and almost flat response from 11.5 to 11.1 kHz and 9.0 to 8.5 kHz. When driven in this manner the filters outputs decrease linearly from 11.0 to 10.0 kHz and 9.0 to 10.5 kHz respectively. These outputs are summed by half wave rectification of the outputs referred to the virtual earth reference voltage. By using the positive going half cycles of one filter and the negative going half cycles of the other a linear response is achieved over the passband. The filters are driven to produce a flat response outside the passband in order to prevent the generation of harmonics if the ideal passband should be exceeded or more importantly when the filter centre frequencies drift slightly due to ageing, temperature or voltage changes. The modulation detectors output voltage decreases with increasing modulation frequency. The components used in the detector are chosen to produce the optimum output between 200 and 560 Hz.

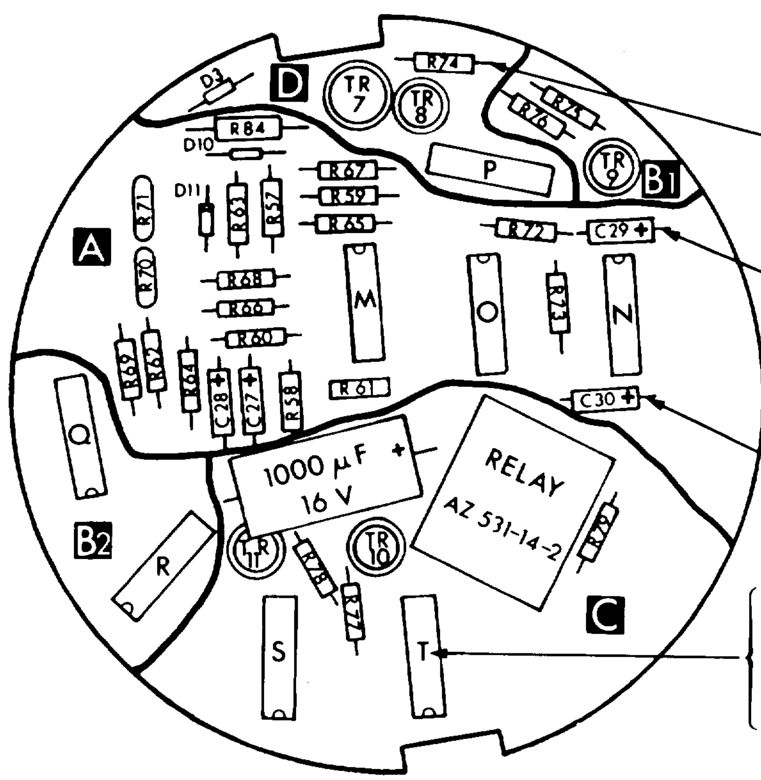
2.2.7 The channel filters are required to respond to a narrow band of modulation frequencies rejecting all others. Several types of filter were investigated and a 'Wien bridge' type active filter was chosen as most suitable. This technique uses a single, low power operational amplifier with two feedback loops. The feedback to one input is a Wien bridge oscillator configuration and sets the channel frequency. The feedback to the other input sets the gain of the amplifier controlling the Q factor and the filters ability to oscillate. The modulation frequency is introduced to the filter by D.C. coupling the detector output to the gain control loop. Modulation frequencies at and near the resonant frequency of the Wien bridge loop induce sympathetic oscillation of the filter. The filter ignores frequencies other than these.

FIGURE 6. CR 200 RECEIVER CARD A AND RELAY CARD B

RECEIVER BOARD A VIEWED FROM COMPONENT SIDE



RELAY BOARD B VIEWED FROM COMPONENT SIDE



TP 11 - I. C. T. PIN 15
TP 12 - I. C. T. PIN 7
TP 13 - I. C. T. PIN 9
TP 14 - I. C. T. PIN 11

In the standard system two of these filters are driven in parallel directly from the detector. If more channels are required a buffer amplifier should be used. The filter response varies with temperature so this must be checked during the initial alignment. The response is set by careful adjustment of the gain control loop and when correct results in typical operational channel widths of 6 Hz at 0^{o}C, 15 Hz at 20^{o}C and 25 Hz at 40^{o}C. In the standard system using a 5.4 volt supply good signal at the channel frequency produces an output swing of three volts peak to peak, while maximum noise signals produce less than one volt peak to peak.

2.3 The operation of functions

2.3.1 Section 2.2 deals with the decoding of what have been termed acoustic command signals. While command is the function of the signals in the CR200 release units the same techniques may also be used for data transfer. The techniques used for putting into operation functions commanded depend on the type of function required. Factors to be considered include: safety; reliability; noise immunity; response time; power; and convenience.

Safety is the overriding factor: functions likely to endanger life or limb must be preceded well in advance by a positive warning, behave in a predictable manner, and be capable of swift and safe immobilisation. Reliability is the second consideration: functions must operate when required: this involves thorough predeployment testing and duplication of potentially unreliable components. The effect of noise on an acoustically controlled instrument while being reasonably predictable in the ocean must also be considered through all the phases of its handling; steam lines, air pipes, hydraulics and a wide variety of other sound sources combined with the unmatched performance of an acoustic transducer in air can simulate control signals although most probably in short and irregular bursts. Response time is governed primarily by the preceding considerations but is also limited by the need to positively identify the command (bandwidth limitation). The operation of some functions can involve switching large currents: mechanical or electrical switches and connectors must be able to handle the desired load and the effect of sudden high current surges on power supplies and other components must be considered. Convenience is important but must fully accommodate the other considerations.

2.3.2 Detection of the operation of a channel filter can be achieved in a variety of ways. A simple analog technique was chosen as most suitable for this low power application: the filter output is half wave rectified; the resultant charges a capacitor; this voltage is monitored by a low power voltage comparator; when the chosen threshold voltage is exceeded the comparators output changes state;

the change of state triggers a monostable multivibrator; the monostable provides the detector output signals and also discharges the detecting capacitor resetting the detector. The values of the detector capacitor and a series, charge rate limiting, resistor set the basic response time of the instrument: between 0.5 and 1 second has been found to be adequately secure in practice. The time constant of the monostable adds to this to provide the minimum retriggering interval: for standard applications the interval chosen is 1.5 to 2 seconds.

2.3.3 Mooring location is achieved by using a command channel to turn on a beacon. The beacon channel is used to operate a latch which switches a 'Darlington' transistor pair to the conducting state. This allows current to flow from the beacon battery to the beacon circuit which then free runs at a crystal stabilised repetition rate. The transistor pair is necessary because of the current drawn by the circuit. The beacon pulses are counted by a binary counter which after a predetermined count resets the latch turning the beacon off. The beacon while being a valuable tool for mooring recovery must not be allowed to interfere with the release operation and so is powered independently and recovery is still possible without its operation.

2.3.4 Mooring release uses a second command channel. This channel independently switches the beacon latch and a second latch which disables the reset counter locking the beacon on (it may be reset by operation of the other channel). The second latch also 'enables' through a transistor buffer (made necessary by differing voltage rails) a second pulse running at the same repetition rate as the first: this indicates that the second channel has been activated. The preceding functions need little security, but the release function can be controlling heavy and potentially very dangerous loads and so requires much higher security. The basic level of security is provided by the method of release activation: a binary counter counts the number of times the release channel detector operates and after 64 counts the number of times the release channel detector operates and after 64 counts activates release. This takes a minimum of 64 seconds and as the beacon is switched on in the double pulse mode after just one operation, at least 60 seconds is provided to take any suitable action. A second level of security is required as, if the release switch were of a semiconductor type, it could fail short circuit and bypass the alarm system; this is provided by using a solenoid operated relay powered by discharging a capacitor through the coil. The capacitor is charged after 32 counts of the release signal and takes approximately 20 seconds to charge. If the controlling switches fail a charge rate limiting resistor prevents adequate relay operating current passing.

FIGURE 7. CR200 OPERATION OF FUNCTIONS CIRCUITS

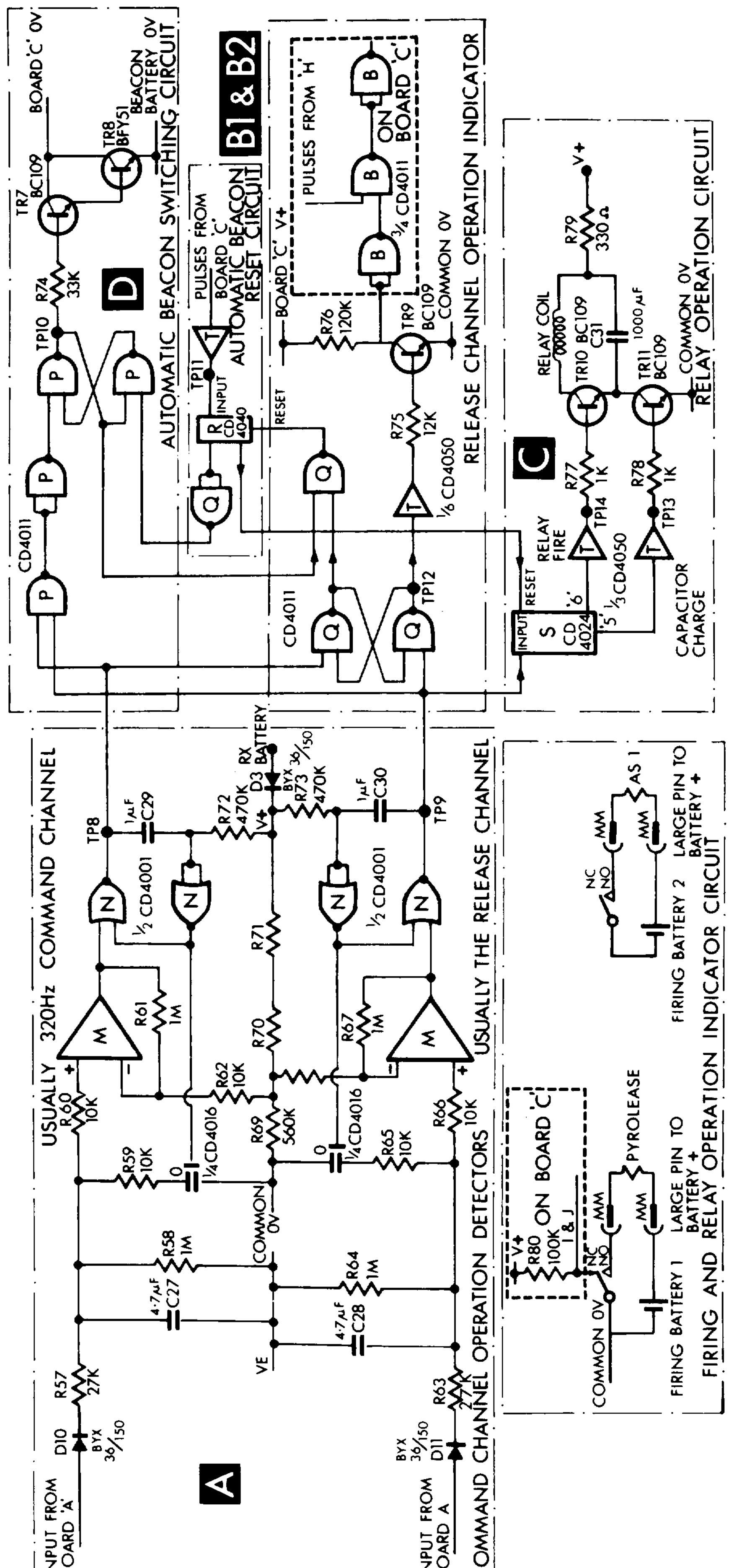
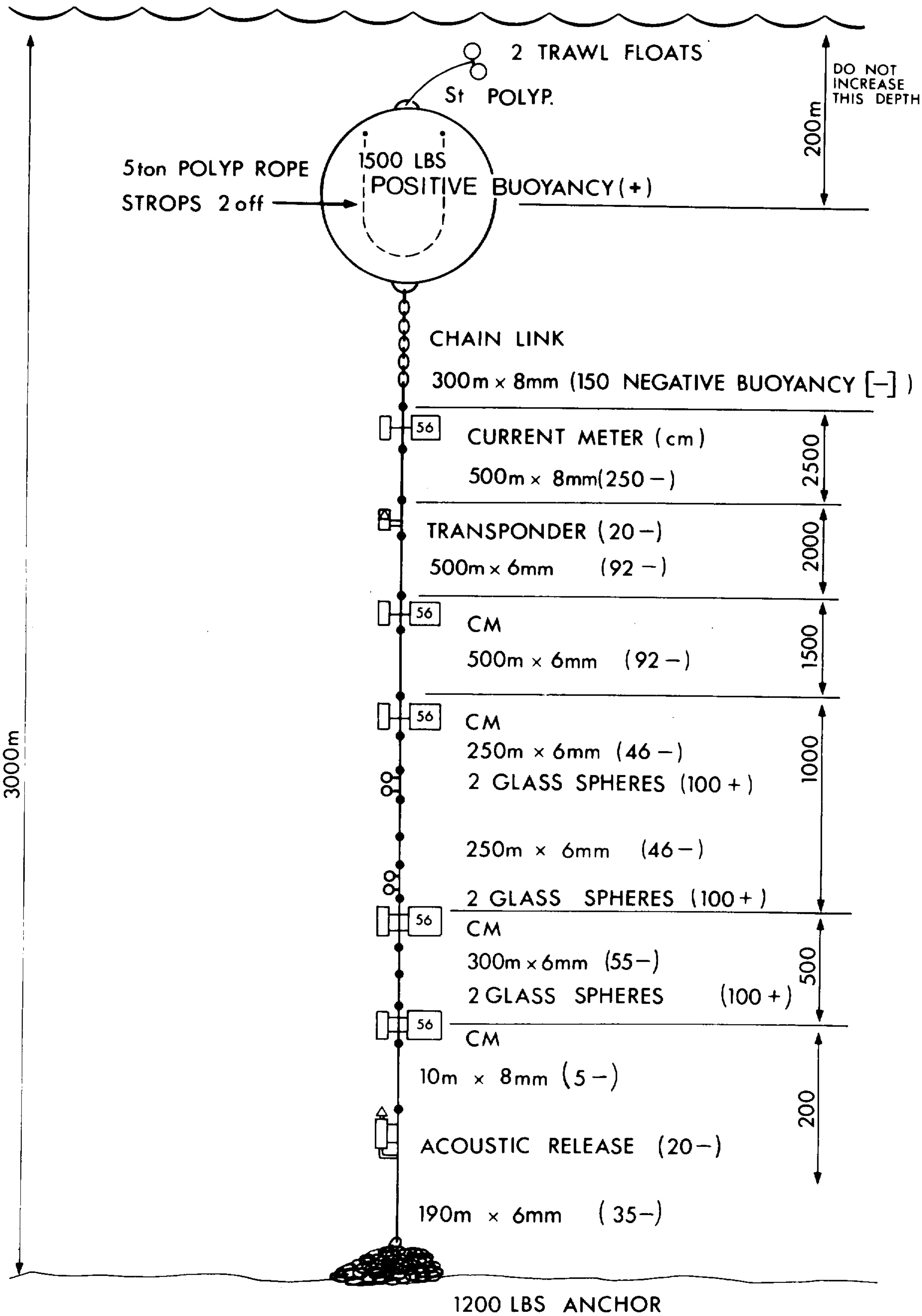


Fig. 8. A Typical Deep Ocean Current Meter Mooring



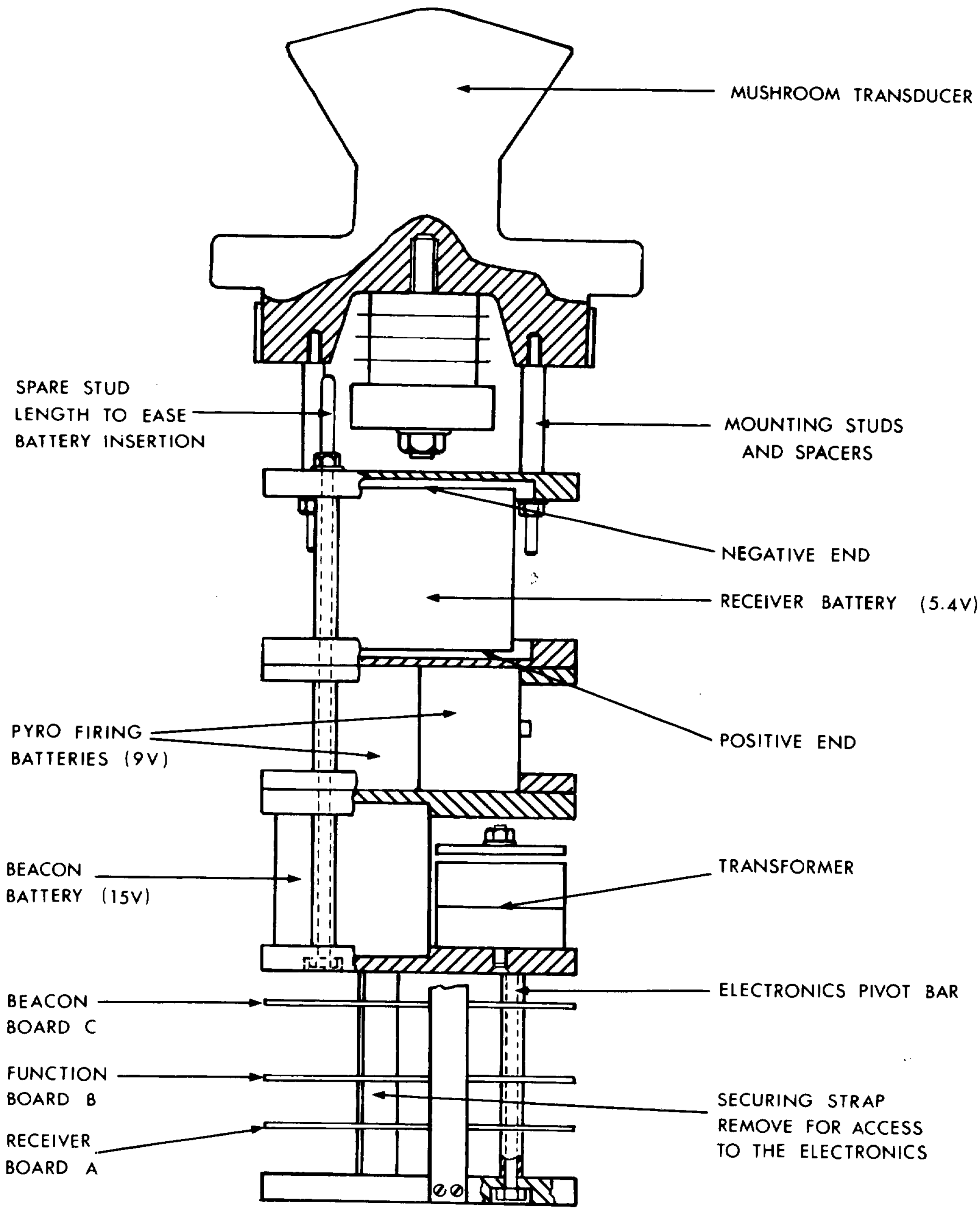
The use of a relay however requires a third level of security; being an electro-mechanical device mechanical shock could bypass the alarm. This protection is provided by using a relay with low-inertia active components and a good shock resistance. The type in use is specified to better than 20 g in any direction and mounted such that shock loads are damped before affecting the relay. Reliability is as important as security in terms of mooring release as failure could result in total loss of months of irreplaceable data. The electronics is thoroughly tested prior to deployment and well proven. However, relay contacts can tarnish increasing their resistance; this is avoided by use of gold plating and a hermetically sealed unit; batteries can deteriorate; only types with a good and proven shelf life are used; 'underwater' electrical connectors and pyroleases have been known to leak - diverting operating power; duplicate firing circuits are used from batteries, through relay contacts and underwater connectors to pyro-leases - the operation of either of which will affect release.

2.3.5 Functions are monitored using a slightly modified and physically rearranged version of the acoustic beacon type H described in Section 3. Logic and power amplifier are run from a common 15V manganese alkaline battery supply although independently decoupled on the board. The supply is adequate to run the beacon for 200 hours at one pulse per second. The beacon's repetition period is coded to one of 14 values between 0.90 and 1.18 seconds using combinations of outputs from the last two decades in the timing chain. One pulse is patched to transmit at the repetition period whenever power is applied to the beacon; a second pulse is gated by a transistor buffer to indicate release channel operation. Relay operation is indicated by a pause in the pulse train (appears as a displacement on the display) produced by disabling the last two decades of the timing chain: the enable inputs of these decades are normally tied to the 0V rail via the normally closed contacts of one side of the relay; when these contacts break these inputs are pulled up to the positive rail by a large value resistor stopping the counters; when the contacts remake the counts continue.

2.4 Physical Arrangements

The physical design of electronic packages to be used in the ocean is normally a compromise between the ideal requirements of the electronic package and the smallest pressure housing that will carry it. Pressure housings are either cylindrical or spherical: the cylindrical type are more compact, easy to handle, and cheaper than the spherical type: the spherical type however offers the optimum volume to weight ratio; for complex packages they can provide the most suitable housings and frequently have sufficient displacement to float the system unaided.

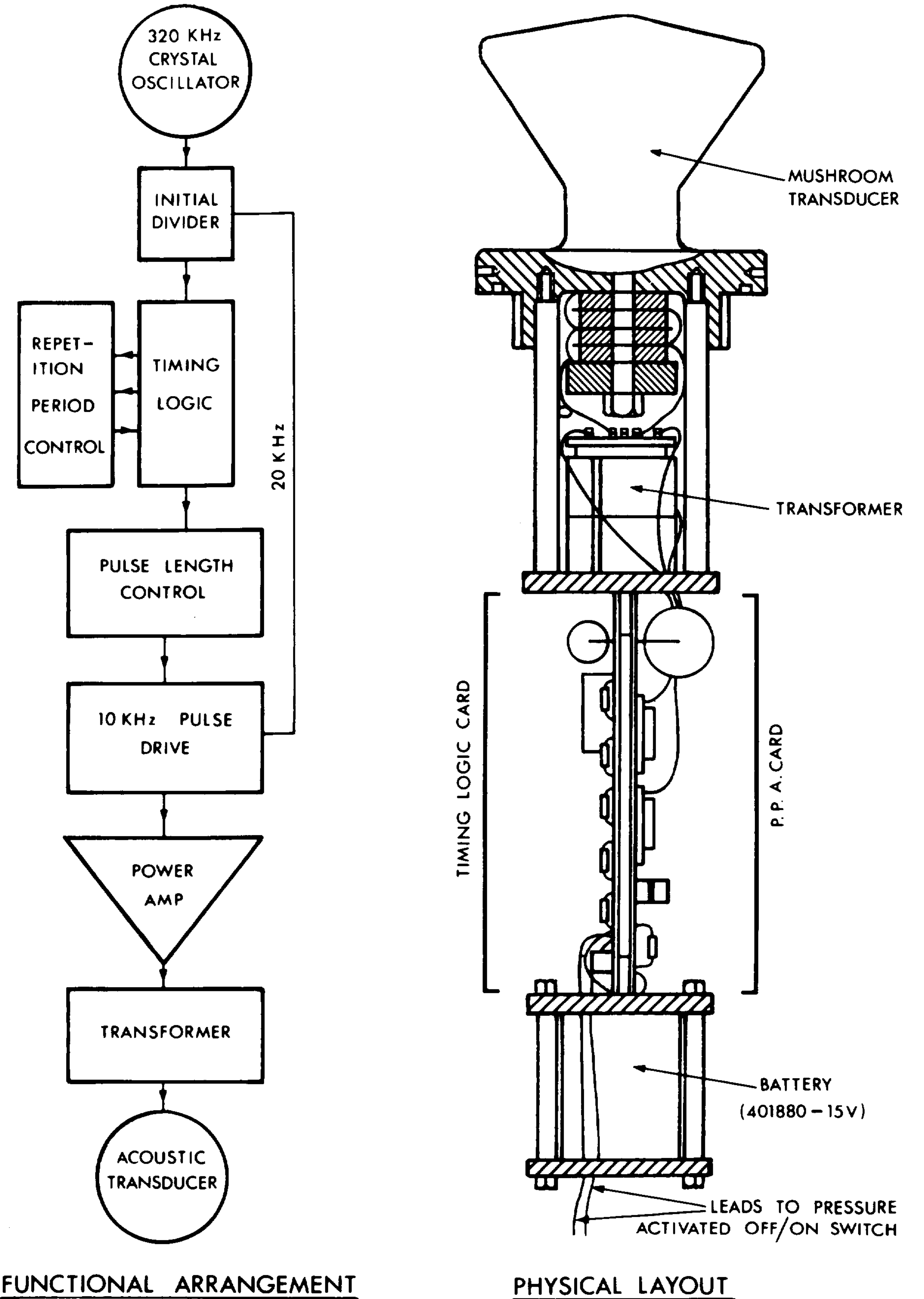
FIGURE 9. CR 200 PHYSICAL LAYOUT



The CR200 electronics has been designed for two sizes of cylindrical housing and a sphere mounted system.

The standard CR200 unit is a self-contained release and location unit capable of operating to depths of 5000 metres. The housing chosen was of 11.5 cms internal diameter: the minimum diameter that would contain the complete receiver circuit on one card; it also allowed the location beacon and function control circuits to be accommodated on individual cards. The complete receiver circuit needs to be on one card to reduce the undesirable effects of unplanned feedback. The layout used is common to all applications and was chosen with great care and patience to ensure reliable and repeatable performance. The high component density requires all interconnections to be hardwired; while being inconvenient for servicing, hardwiring is a positive reliability advantage for long term immersed systems. The three cards require 7.5 cms tube length. The matching transformer, battery packs and chassis necessary increase the overall electronic package dimensions to 30 cms long by 11 cms diameter.

FIGURE 10. ACOUSTIC BEACON TYPE H. FUNCTIONAL ARRANGEMENT & PHYSICAL LAYOUT



3. BEACONS

3.1 The acoustic beacon type H provides the basis for remote telemetry of information to ranges of twelve kilometres. Timing is controlled by a quartz crystal oscillator giving an accuracy of better than 1 in 10^6 per day and per ^{o}C.

The uses of this equipment include:-

1. on vertical wires to indicate separation from the sea bed and operation of equipment;
2. on towed bottom nets, dredges and grapples to indicate bottoming and operation;
3. on a variety of nets and other sampling systems to monitor depth, temperature, flow, state of net, and other parameters: fully described in Remote Monitoring Systems;
4. in the command system to locate untended bottom instruments, sub-surface and surface moorings.

Timing is restricted by the need to identify pulses, the job the beacon is being asked to perform, and restrictions of size, weight, and handling. At 10 kHz, using the standard system, the minimum practically identifiable pulse length using pulse-to-pulse correlation techniques is 1 millisecond to approximately 1.5 kilometres and 2 milliseconds to approximately 12 kilometres. Using a purely electronic system rather than facsimile recording 2 msec is probably the lowest detectable at all ranges (represents 20 cycles of signal). 12 km is the limiting range under straightforward 10 kHz propagation; shallow water reduces this (may be as much as 100 times less) due to inevitable losses by reflections at surface and sea bed. The beacon can be simply wired to produce pulse repetition periods from 2 msec to 2 secs in 0.2 msec steps and to produce a wide range of pulse lengths. Transmission or reference frequencies are available from 320 kHz to 2.5 kHz in binary steps. As standard pulse repetition rates in bands of 0.45 to 0.55 secs, 0.90 to 1.18 secs, and 1.8 to 2.0 secs and a transmission frequency of 10 kHz are used. These enable use with the standard IOS 10 kHz precision echo-sounder systems. Pulse lengths used are typically 1,2 or 4 msecs. When using pingers for relocation, a pulse repetition period near one second and a 2msec pulse length has been found to permit easy manoeuvring and identification; a ship moves 1 metre in 1 second at 2 knots. With very simple modifications extra pulses may be introduced or pulse repetition period varied to indicate such things as tilt or function switching. The monitoring of continuously variable parameters require considerably more complex techniques (see Remote Monitoring Systems) but do make use of many of the facilities provided by the basic beacon.

3.2.1 Timing logic is low power CMOS with its restricted voltage range of 5 to 15V. This does not limit the transmission power as the power stage has a decoupled supply, however as heatsinks are not normally used operating voltage is restricted to the range 10 to 35V. The beacon may be broken into a series of functional blocks: the 320 kHz crystal stabilised oscillator provides a precision reference frequency; the basic timing control counts this frequency and provides a large selection of accurately timed outputs; the repetition period control combines some of these outputs to control the beacon pulse repetition period; the pulse length and timing control takes other outputs and uses them to produce unique pulses suitable for transmission; the external and internal indicators gate some of these outputs using the pulse mixer to produce pulses indicating operation of a selection of parameters; the drive pulse control and antiphase generator take the pulses and convert them to a frequency and phase suitable to drive the pulse power amplifier; this in conjunction with the matching transformer drives the acoustic transducer with the required power.

3.2.2 The oscillator and timing chain The oscillator comprises a DT cut crystal with a pi-type feedback network and a suitably biased CMOS inverter as amplifier in a parallel resonant configuration. The performance of the amplifier varies with the type of inverter used requiring some component changes to suit the NAND or NOR types. Frequency trimming is possible by variation of the parallel capacitance but the practical effect of the variation from the nominal 320 kHz produced by use of standard values is not significant. The value of 320 kHz was originally chosen as a compromise between physical size and current consumption.

The 320 kHz is divided down by a seven stage binary divider with all outputs accessible. This provides frequencies of 160 kHz, 80 kHz, 40 kHz, 20 kHz, 10 kHz, 5 kHz, and 2.5 kHz. The 5 kHz is used to clock a serial chain of four decade dividers; these are the basis of the beacon's flexibility. Each decade has ten sequentially clocked outputs, one divide by ten output, a reset control and a clock enable control. Activation of the clock enable control halts the counter sequence, when control is removed the counter restarts from the point it had reached; this is used to introduce delays in pulse sequences. Activation of the reset control returns the state of the counter to the zero condition; this is used to vary the repetition rate of outputs from that and following counters. The divide by ten output changes state at five and ten counts after the zero condition. The ten sequential outputs change to the positive state for one period of the input signal then returning to the negative state until recycled.

FIGURE 11. ACOUSTIC BEACON TYPE H CIRCUITRY

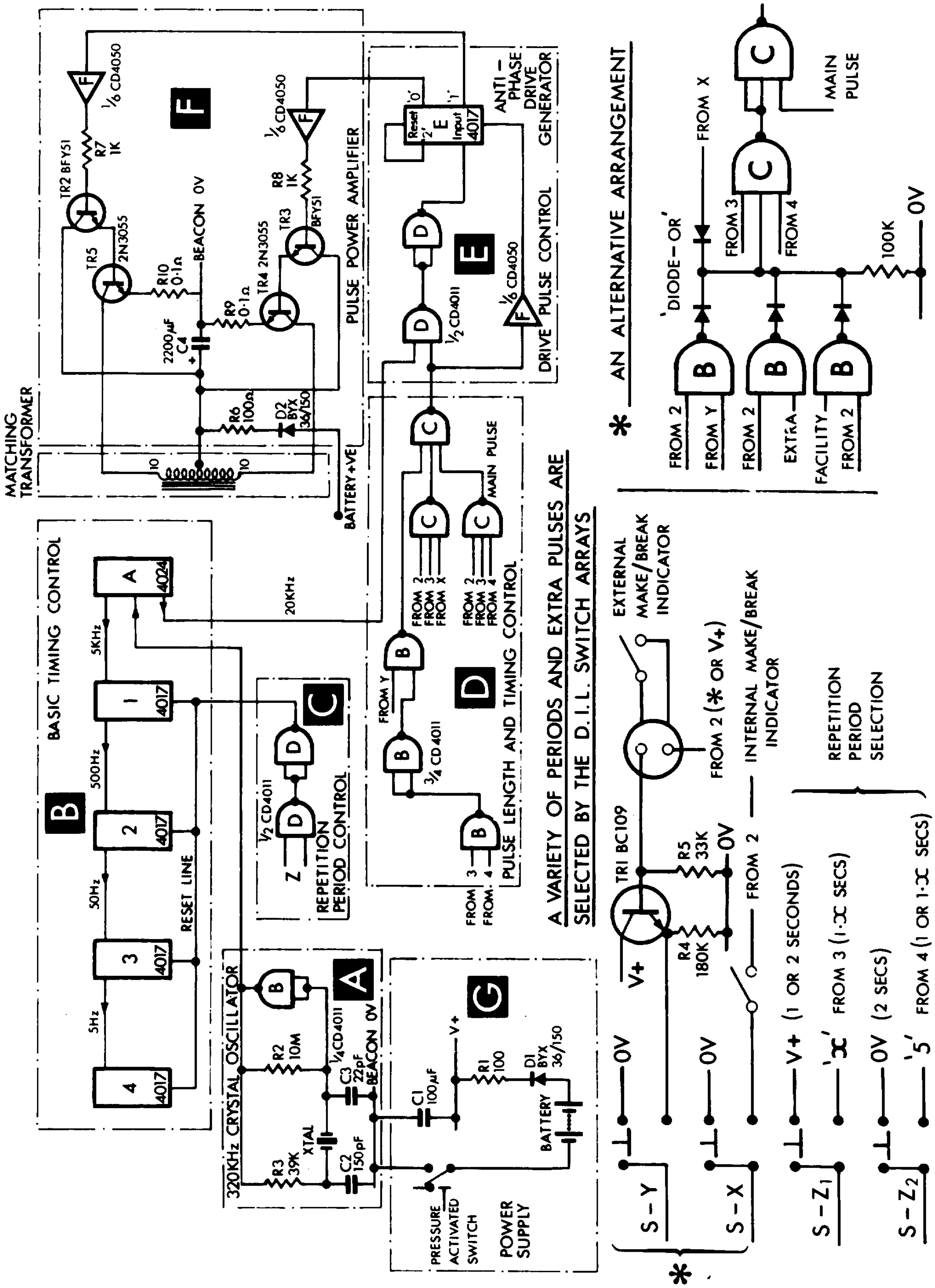
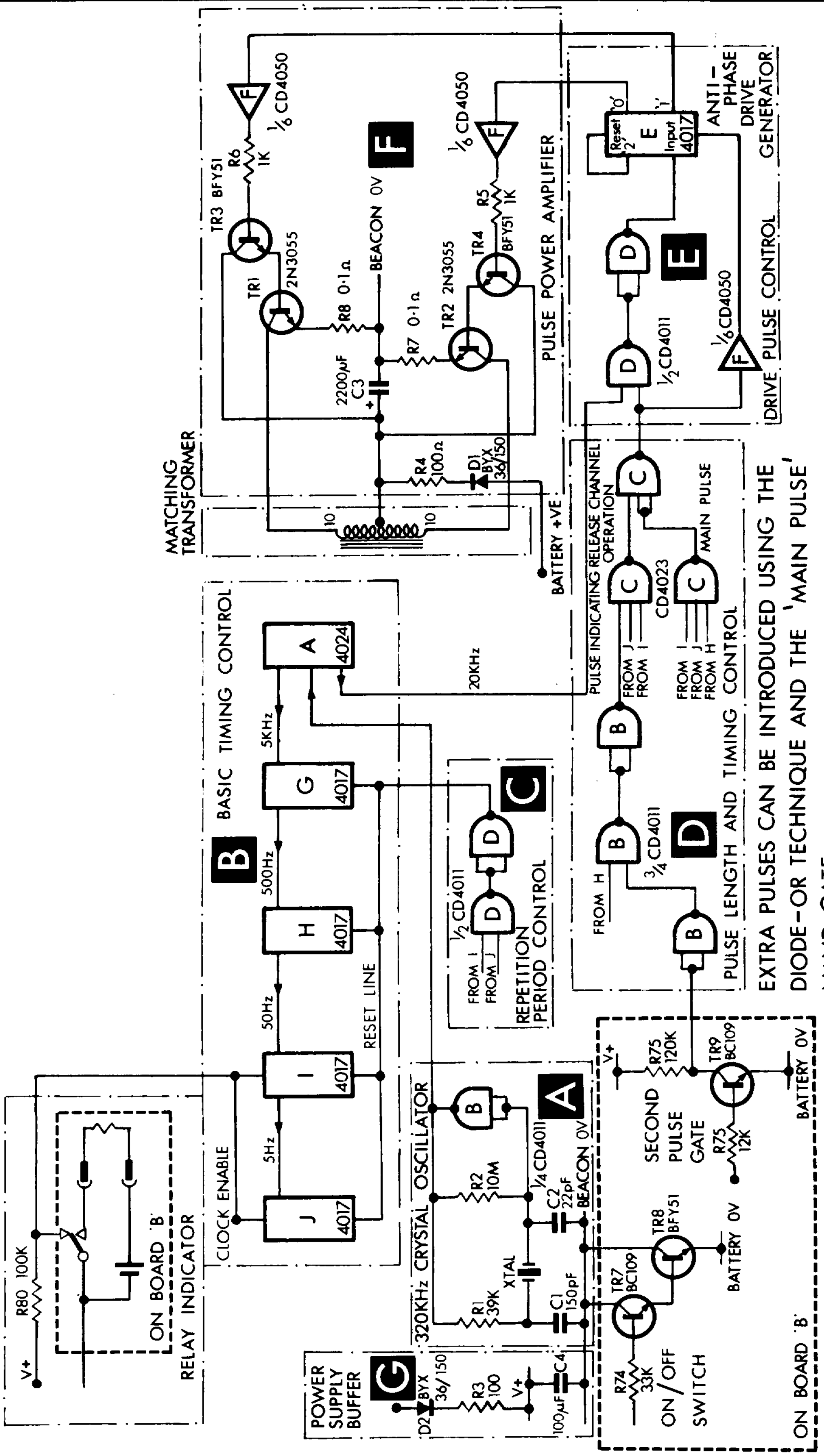


FIGURE 12. BEACON CIRCUITRY AS USED IN THE CR200 RELEASE



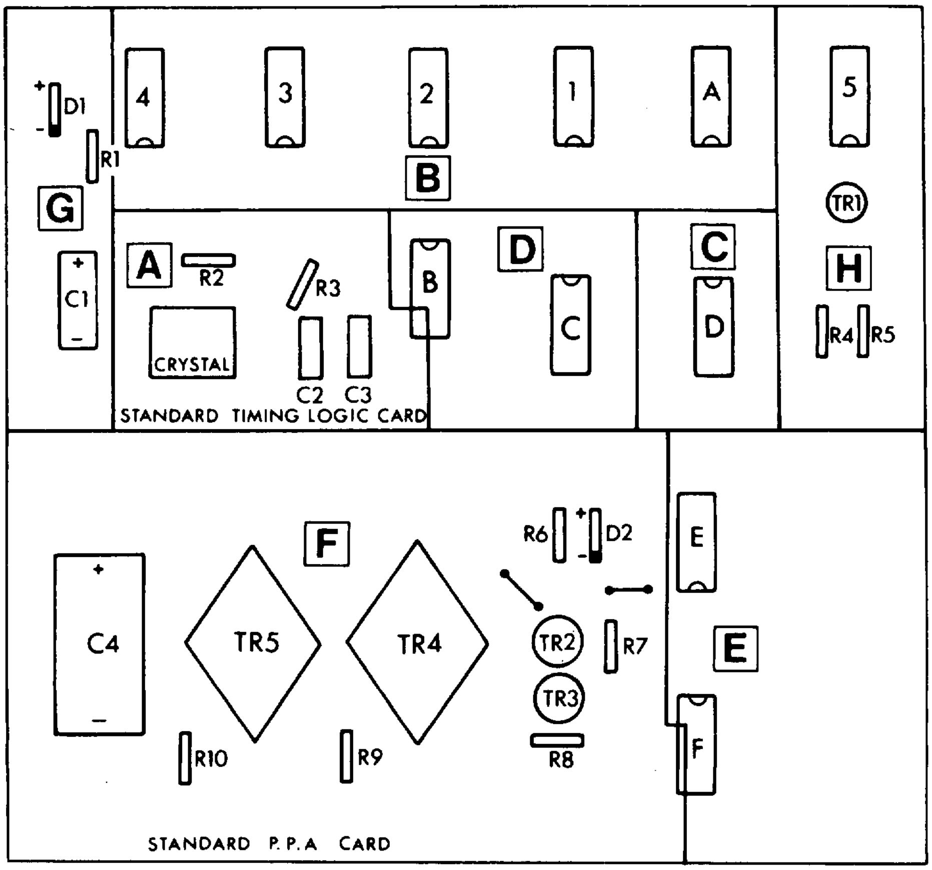
The first decade is clocked at 5 kHz; the sequential outputs therefore are positive for 0.2 milliseconds (ms) and repeat every 2 ms; the divide by ten output runs at 500 Hz; this clocks the second decade whose sequential outputs are 2 ms long and repeat every 20 ms. The clock enable and reset controls of these two decades are tied to the OV rail permitting them to continuously free run as described. The succeeding two decades when allowed to free run have sequential outputs of 20 ms and 200 ms duration and repeat every 200 ms and 2 seconds respectively; their clock enable lines are normally tied to the OV line except when used with the CR200 release (2.3.5).

3.2.3 Repetition period The reset function is used when there is a need to identify a particular beacon in the presence of others and when the greater resolution of the facsimile recorder faster sweep rates is required. The CR200 system requires individually identifiable units to allow accurate navigation and release monitoring in dense mooring arrays. The coding is achieved by mixing pulses from the last two decades such that when a pulse from each coincide the counters restart from their zero state; a two input NAND gate does the mixing then the output is inverted to apply the control in the correct sense. The counter repetition rates useable are restricted by the range of drive rates tolerated by the standard P.E.S. Mk III recorder and by the minimum unambiguous rate separation; the standard range is 0.90 seconds to 1.18 seconds in 0.02 second steps. The 1.00 second rate is reserved for standard beacon applications: this rate is standard on the P.E.S. Mk III recorder; allows operation without a deck control unit; produces a finer line on the recorder from the two millisecond pulse; and allows full use to be made of the recorders internally generated scale (400 or 300 divisions full scale depending on selection of 'fathoms' or 'metres').

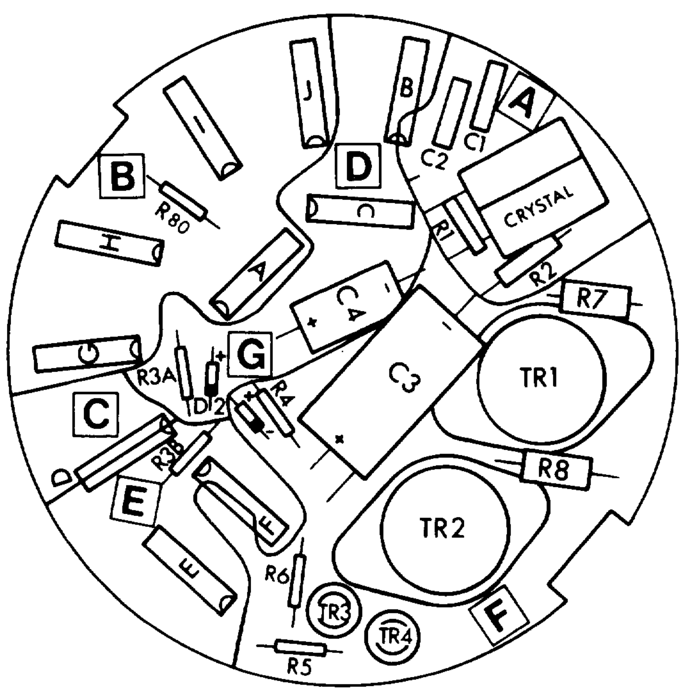
3.2.4 Pulse derivation The major purpose of the beacon logic is to provide a pulse of 10 kHz for the acoustic transducer to transmit; the pulse must be long enough to allow easy identification; short to reduce power consumption (and thus battery requirement); accurately timed to ease interpretation; when used with the CR200 command circuits the electronics must also be electrically quiet at the command operating frequencies (most significantly 9 to 11 kHz).

The pulse envelope length may be accurately controlled by mixing pulses from the four decades in the timing chain; resolution is possible in 0.2 ms steps. In practice, a 2 ms pulse length serves the majority of requirements and is achieved using a 3 input NAND gate to mix one output from each of the last three decades. The minimum number of useful pulses per repetition cycle is obviously

Fig. 13. Acoustic Beacon Circuit Board Component Layouts.



COMBINED
CIRCUITS
AS USED
IN THE
CR200
RELEASE



one so in cases where the cycle is less than two seconds care must be taken to ensure that the pulse selected from the last decade in the chain does actually occur.

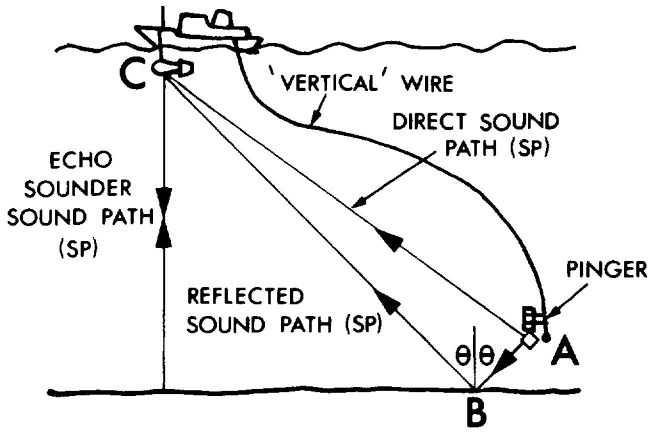
Additional pulses may be introduced in a cycle period by simple logic techniques; for instance, a 'diode-OR' mixer used with the basic 3 input NAND mixer: these pulses can be simply gated by high to low impedance (make or break) type switches if housed in the same pressure case; external switches must be buffered to match impedances; temperature and pressure effects or assembly in humid or sea air conditions can reduce impedances on long cable runs or between pins on multipin connectors to very low values (can be as low as 500 ohms).

3.2.5 Pulse conditioning A somewhat unusual technique is used to convert the pulse to a form suitable to drive the power amplifier. The pulse envelopes produced are used to gate (i) a 20 kHz signal derived from the timing chain and (ii) the positive supply of a decade divider (type 4017). The decade divider is driven at its input by the gated 20 kHz and reset by its third output ('2'); this results in pulses of 10 kHz appearing at the dividers first and second outputs ('0' and '1') of identical length but opposite in phase; it is necessary to gate the dividers power supply to avoid leaving one of the outputs in the positive state. This arrangement avoids the use of 10 kHz except during transmission pulses - protecting the receiver circuits - and provides the drive for a push-pull type power amplifier without the use of a transformer.

3.2.6 Output pulse power amplifiers There are two basic types of acoustic transducer used with the beacon: the 'mushroom' design using a mass-loaded stack of ceramic discs and the 'ceramic ring' design using a free, short cylinder of ceramic. The ceramic ring design is less efficient and therefore requires a higher electrical drive to achieve the same acoustic power level as the mushroom. The acoustic directivities are considerably different; the ceramic ring giving better horizontal ranges in shallow deployments (less than 1,000 metres), the mushroom giving better slant ranges in deep deployments (greater than 500 metres). The electrical impedances are also considerably different. The two power amplifiers used are tailored to these three requirements: efficiency, required range, and electrical impedance.

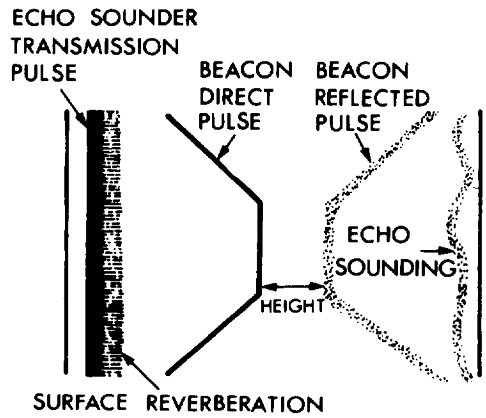
3.2.6(a) The impedance of the mushroom transducer is of the order of 2000 ohms and its conversion efficiency is greater than 80%. The operational requirement is

FIGURE 14. VERTICAL AND TOWED BEACON WORK.



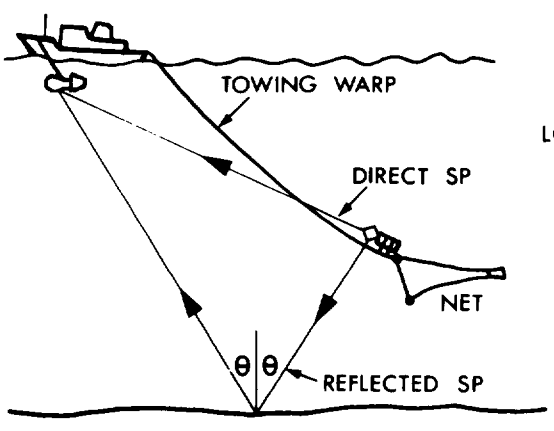
VERTICAL SCALE COMPRESSED – θ SMALL

FACSIMILE TRACE



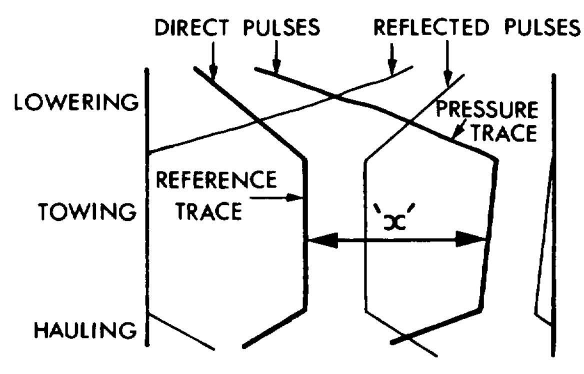
In deep water the height of the pinger above the sea bed is $\frac{AB + BC - AC}{2}$ which is half the time difference between the reception of the direct pulse along path AC and the reflected pulse along path ABC multiplied by the average sound velocity: time (sec) × sound velocity (m/sec) = height (m).

VERTICAL



θ LARGE

FACSIMILE TRACE



The separation 'x' is measured and used with the laboratory calibration to determine the depth of the net - bottom reflections from midwater towed pingers are not suitable for depth determination due to the uncertainties in the geometry involved.

TOWED

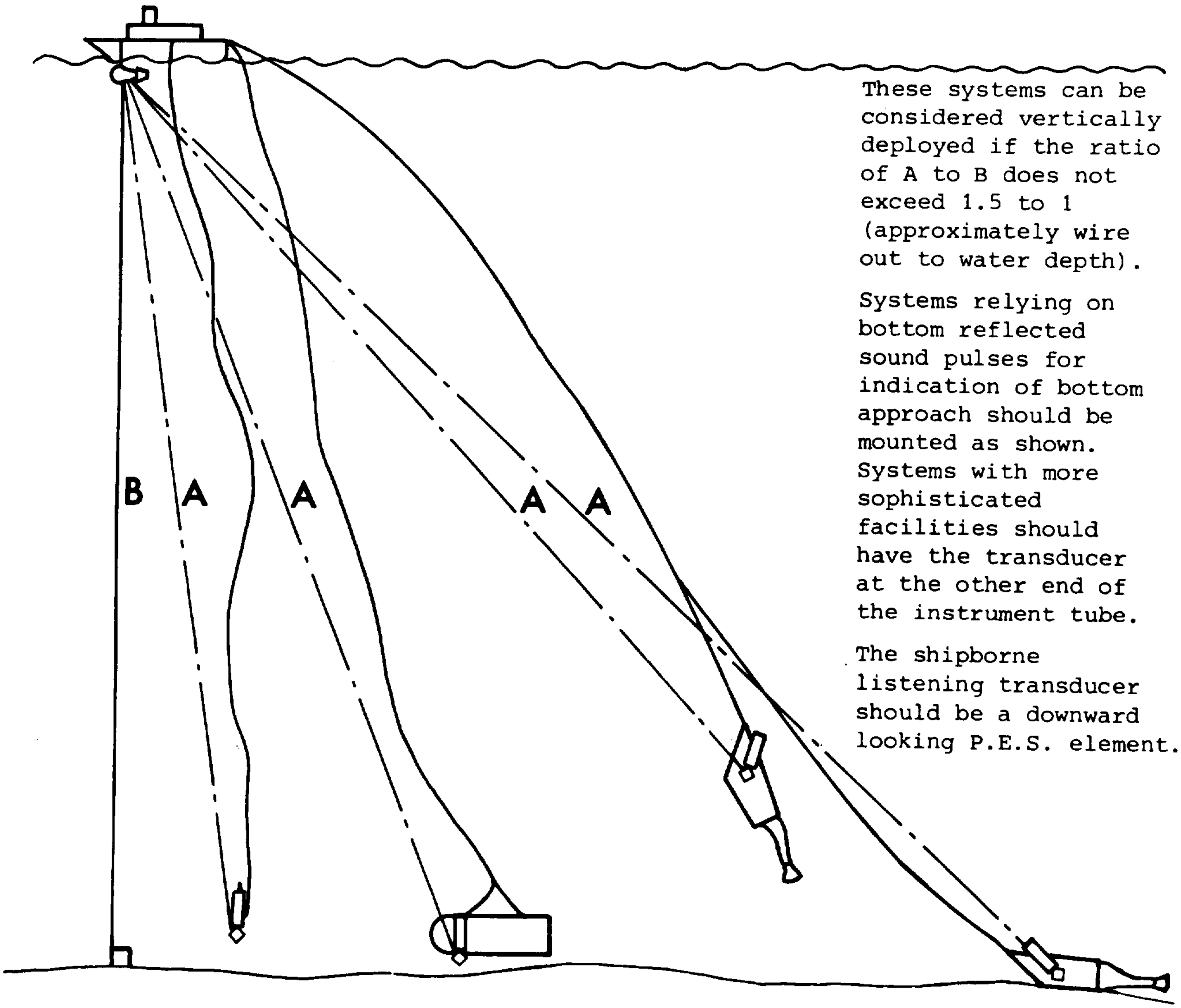
to be easily resolvable at a maximum slant range of 10,000 metres when deployed at a depth of 5,000 metres; this is achieved comfortably with an acoustic power output of 20 watts. The minimum necessary electrical power to reliably produce this from all mushroom transducers is 25 watts. The remaining constraints are battery performance, impedance matching, reliability and convenience.

It is most convenient to run a self-contained system from a single battery supply; the timing logic restricts this voltage to 15 volts. To obtain the required power at the transducer requires a transformer to match the impedances. A considerable current must flow in its primary winding to achieve the power required. This current must be delivered reliably at low temperature which restricted the choice of battery type - manganese alkaline, mercury (only certain constructions), or lithium based. Manganese alkaline was the most suitable but suffers from a marked drop in voltage during its useful life. An end point voltage of 10 volts was considered acceptable as long as a push pull configuration was adopted to restrict the peak current required by doubling the primary voltage. Large power transistors were used to avoid the need for extra heatsinks and to increase reliability (by running them below their maximum ratings). These transistors (NPN type 2N3055) are low gain so had to be driven by smaller transistors (BFY51) in a Darlington configuration to match the CMOS drivers to the required power levels. The final circuit is as figure .

3.2.6(b) The impedance of the ceramic ring transducer is of the order of 500 ohms, its conversion efficiency about 50%, and its directional properties spread a given acoustic power over a greater useful area (resulting in lower peak levels) than the mushroom transducer. The operational requirement is to be resolvable at a maximum slant range of 8,000 metres when deployed at a depth of 2,000 metres; this is comfortably achieved with an acoustic power of 20 watts. The minimum necessary electrical power to reliably produce this from all ceramic ring transducers is 50 watts. The remaining constraints are as with the mushroom transducer.

Impedance matching is achieved by using a choke in series with the ceramic ring and altering the transformer ratios. The extra power is handled by increasing the current in the primary winding; the BFY51-2N3055 combination has insufficient gain to achieve this so the 2N3055 is replaced by a 'Darlington power transistor' (MJ3001); this still requires some of the gain of the BFY51 but the drive from the CMOS is considerably reduced. The final circuit is as figure . Both circuits can use the same printed circuit layout.

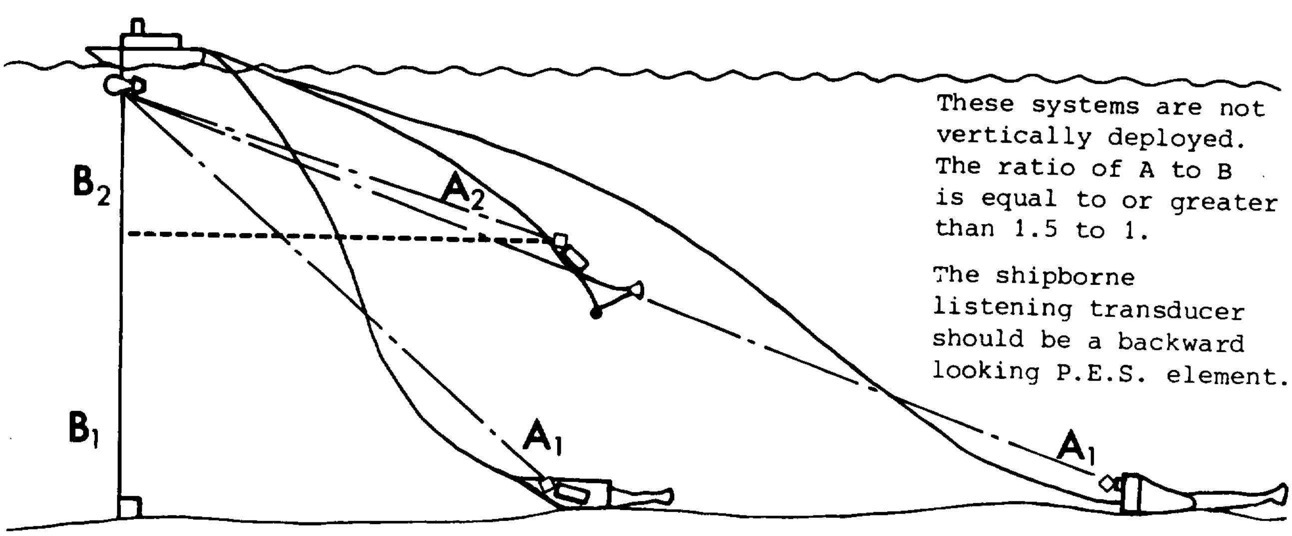
FIGURE 15. WHAT IS 'VERTICAL'?



These systems can be considered vertically deployed if the ratio of A to B does not exceed 1.5 to 1 (approximately wire out to water depth).

Systems relying on bottom reflected sound pulses for indication of bottom approach should be mounted as shown. Systems with more sophisticated facilities should have the transducer at the other end of the instrument tube.

The shipborne listening transducer should be a downward looking P.E.S. element.



These systems are not vertically deployed. The ratio of A to B is equal to or greater than 1.5 to 1.

The shipborne listening transducer should be a backward looking P.E.S. element.

3.3 Using Beacons

3.3.1 Initial Conditions The first requirement is a full shipborne monitoring system: receiving transducer, interface unit and display unit (described in other Parts of Report 96). The second requirement is a suitable beacon; the correct acoustic transducer, pressure vessel, power supplies and indicators for the application. The third requirement is a suitable mounting for the beacon.

3.3.2 Specifying a requirement Particular special versions of the beacon are described in Section 5 and the general conditions of use are described in Part One of this series. Some other important points are:

Free running moored beacons can be detected by anyone with suitable 10 kHz equipment; switched beacons are more secure but more expensive and require suitable interrogation equipment (consider transponders, Section 5).

External events to be monitored by simple beacons should result in the operation of a simple 'make or break' type switch at the point of operation; the cable run connecting this switch to the beacon should not exceed a length of 3 metres.

External events requiring more complex monitoring than the simple on/off technique cannot be monitored by a simple beacon; these events require a 'Net Monitor' type beacon; they should produce a frequency compatible with the Net Monitor delay technique at the point of operation; will require careful calibration under simulated operational conditions before deployment and with the shipborne display to be used.

Monitor a sufficient number of events to adequately describe the operation of the sampling system.

Investigate the available technology carefully before asking for a specific instrument; the bottom reflected signal of a simple beacon is nearly always adequate to describe separation from the seabed in depths to 2000 metres BUT in depths of 5000 metres in areas of soft sediment and/or high current shears a short range echosounder interfaced with a 'Net Monitor' type beacon might well be a better solution.

External indicators and cables should be rugged enough to withstand normal shipborne handling techniques as well as the deployed operating conditions.

3.3.3 Mounting a beacon The acoustic transmission path to the ship must be completely unobstructed and form a suitable part of the acoustic transducer; if a bottom echo is required that path must be unobstructed and form a suitable part of the acoustic transducer.

FIGURE 16. OPERATING PRECAUTIONS AND TEST PROCEDURES

General

Do not arm release devices of ANY type until the last possible moment; before arming check all electrical connections are inert and that all work in the vicinity of the release has been completed.

Before every deployment:-

check tightness of nuts, bolts, end caps, etc; check tightness of electrical penetrators (but DO NOT overtighten) and the integrity of plug-in connections.

After breaking a watertight seal:-

clean, check and regrease (with petroleum jelly) 'O' rings and 'O' ring surfaces.

Command Systems

The alignment of tuned circuits should be checked yearly as should the channel filter operating bandwidths at $0^{\circ}C$.

Before operational deployment of any command sea unit the channel filter bandwidths and the operation of function should be checked on a vertical wire at or near the proposed depth and temperature; if the bandwidth differs by more than a few hertz from the $0^{\circ}C$ values and the proposed deployment exceeds one month the slow drift of the electronics may either cause premature operation or prevent operation.

Before deployment Aluminium pressure cases should be liberally coated with petroleum jelly which assists the anodised film surface protection. Stainless steel 316S16 should be deployed clean and unprotected; some experimental research recently published suggests low carbon steel or aluminium anodes can be successfully used to prevent crevice corrosion but at October 1981 IOS has no practical experience confirming this.

After final recovery the external mechanics should be stripped to component parts and inspected; suspect parts should be replaced and all stainless steel repassivated before reassembly.

Modern transducers used in beacons on moorings, vertical and slow-towed attached wires (where wire out to beacon depth does not exceed a ratio of 3 to 2) should be aligned vertically.

Mushroom transducers used in beacons on fast-towed or high drag attached wires (where the ratio normally exceeds 3 to 2) should be aligned horizontally pointing towards the ship: at ranges exceeding 5000 metres they should also normally be monitored using a backward looking P.E.S. type transducer.

Ceramic ring transducers are normally aligned vertically (major directional sensitivity in the horizontal plane).

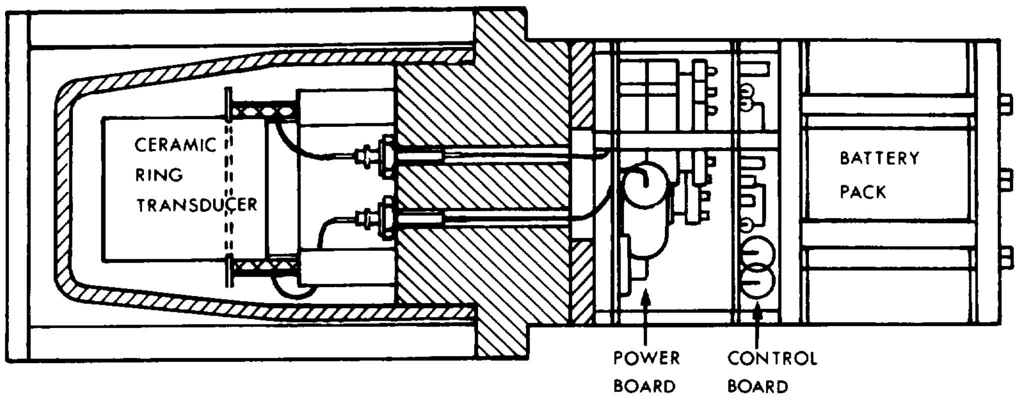
3.4 Physical Arrangements

The constraints on physical design are as mentioned in Section 2.3.5 as is the physical arrangement of the beacon when used in the CR200 sea unit.

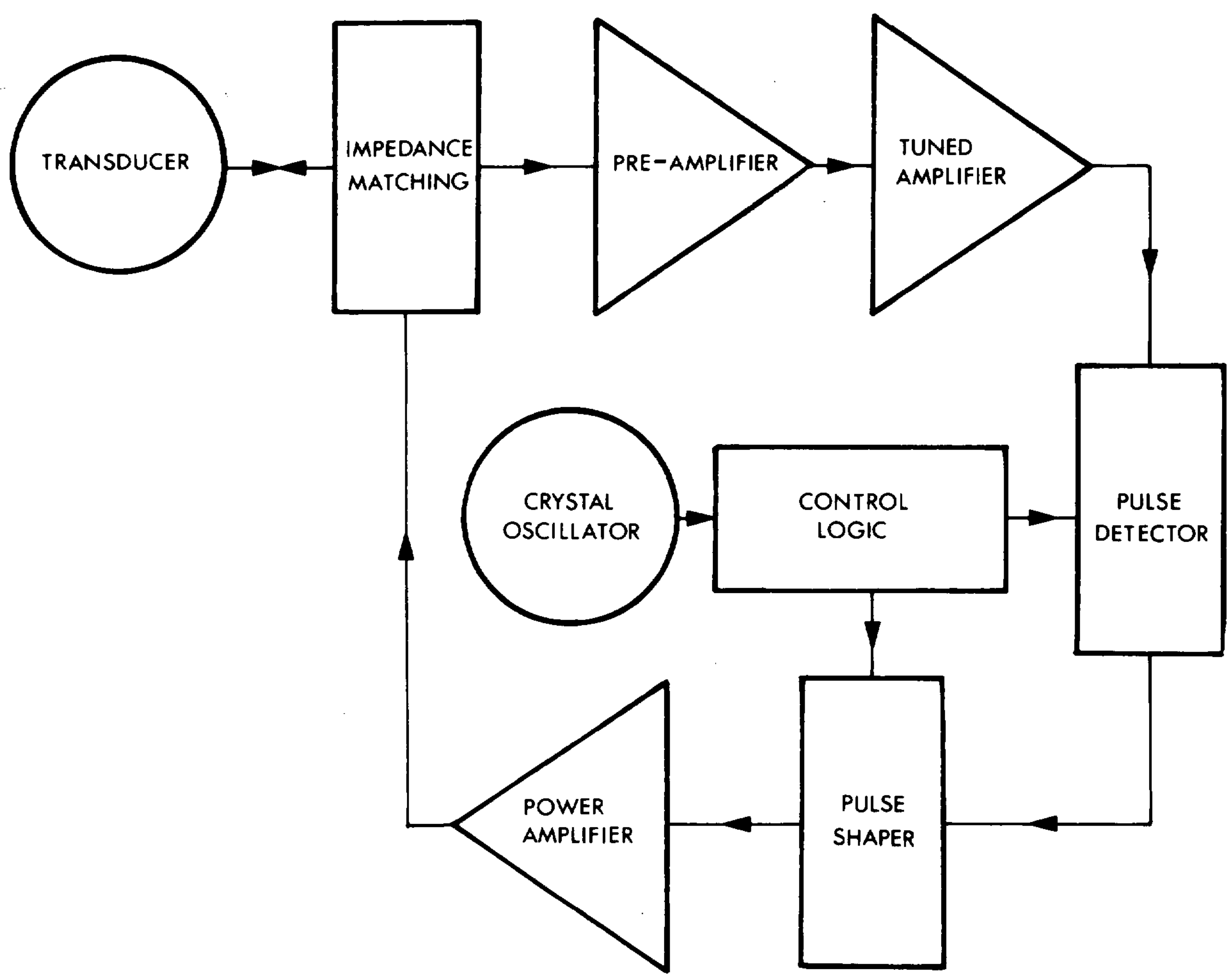
The standard Acoustic Beacon type H is designed to fit an aluminium pressure case of 7.5 cms inside diameter and requires an internal unobstructed length of 25 cms plus 5 cms for mushroom stack. The 11.5 cms diameter card can be used in a self-contained form requiring an internal length of 11 cms plus 5 cms for the mushroom stack. To these must be added thread length, end cap thickness, mushroom length and if used, pressure switch length. The two versions are drawn in Figure .

FIGURE 17. LIGHTWEIGHT TRANSPONDER

PHYSICAL LAYOUT



FUNCTIONAL DIAGRAM



4. TRANSPONDERS

4.1 General Principles

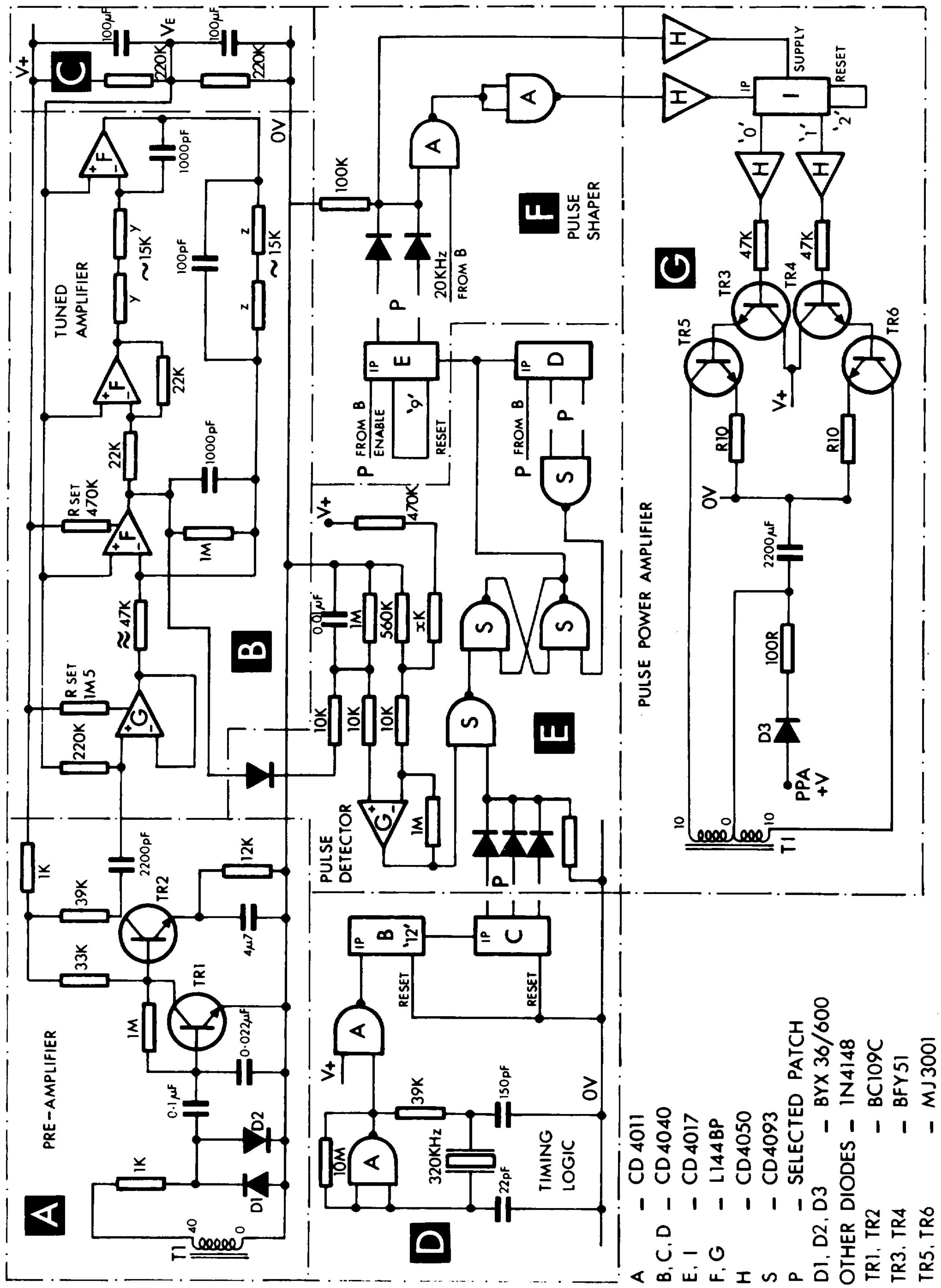
For navigation with respect to and location of acoustic transponders the major requirement and limiting factor is that they respond to the majority of interrogations and do so in a predictable manner. Obstacles to this performance include sea noise, ship noise, interrogation pulses arriving by refracted and reflected paths, response pulses returning to the transponder by reflected paths (sing around), and pulses generated by adjacent units. Sea noise and ship noise may be eliminated by suitable sensitivity and threshold settings in the amplifiers and at 10 kHz are relatively insignificant. Advantages possessed by the interrogator are (a) response is required to the pulse taking the shortest path which should arrive in a 'quiet' ocean first and (b) interrogation repetition may be accurately controlled. The transponder could be made to respond to every pulse received whatever its source but this wastes power and can lead to very confusing signal returns. So a first control is to switch the detection circuitry off for a set period after a response. This 'dead time' cannot be exactly the interrogator repetition period as relative motion of interrogator and transponder can produce periods apparently shorter than the transmission rate. Thus it is possible for situations to occur where alternative pulses can 'capture' the transponder's attention.

Other deterrents to the transponder locking on its own reflected signals are the techniques of: listening at one frequency and responding at another, the automatic blocking of reply pulses at suitable intervals, and reducing the output power to the minimum consistent with required range.

4.2 The lightweight 10 kHz transponder

4.2.1 Basic techniques This transponder has been designed as a relatively lightweight multipurpose unit. In its standard form it can use either mushroom or ceramic ring transducers, listen continuously for two years, and respond to continuous 1 second interrogation for 200 days. Its primary role is to mark the upper sections of long moorings; typically this requires response from a slant range of 4000 to 6000 metres from a position 200 to 600 metres below the surface from any direction of approach; therefore the normal transducer used is the ceramic ring. To enable ease of identification by ships fitted with the IOS Precision Echo Sounder (PES) Mk III system the units both listen to and respond with 10 kHz (in some cases obviating the need for extra shipborne equipment); the sing around problem is partially reduced by the poor vertical sensitivity of the ceramic ring but depths of 340 to 380 and 680 to 750 metres can be a problem with

FIGURE 18. LIGHTWEIGHT TRANSPONDER CIRCUIT



some units. To reduce the sing around and false triggering problems, a dead time of 0.92 seconds is used (complementing the normal 1 second repetition of the echo-sounder/interrogator) and reply is totally disabled for three seconds in every 12 seconds; this also extends battery life. Power output and receiver sensitivity are set to comfortably achieve the required range.

The standard unit replies with two closely spaced pulses; this spacing may be varied to allow up to seven units to be individually identified.

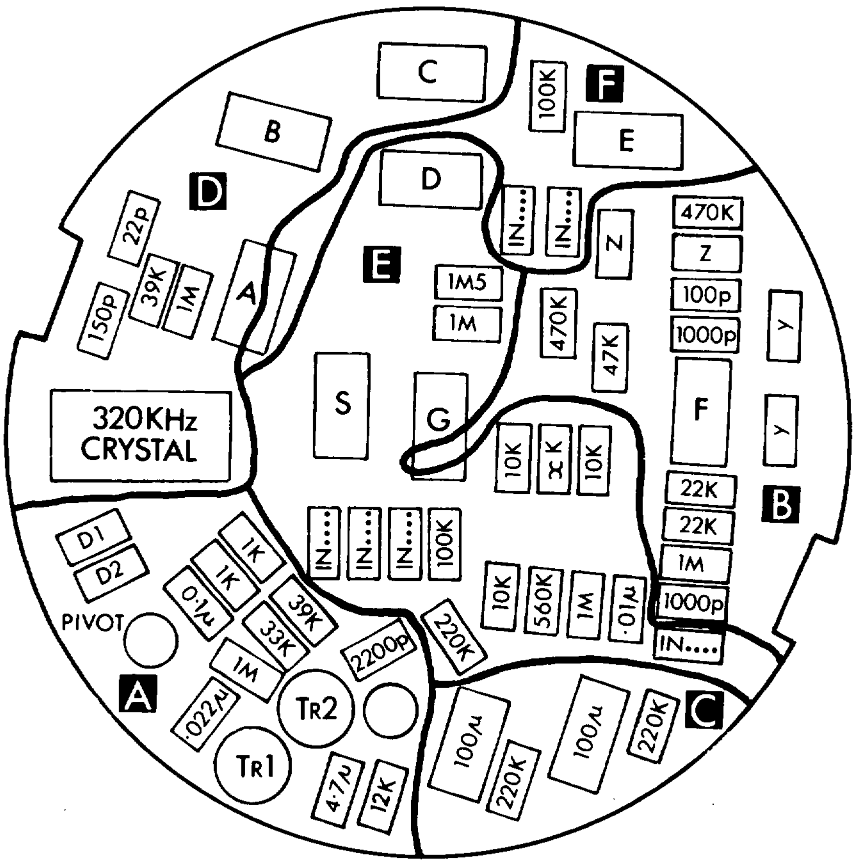
Variations possible with this system are the ability to respond to any frequency in the range 2 kHz to 30 kHz by only simple tuning and transducer changes, and the ability to respond at a variety of crystal controlled frequencies in that range by simple patching changes.

4.2.2 The receiver The acoustic transducer is matched to the preamplifier as in 2.2.2. The pre-amplifier is wideband and uses BC109C low noise, high gain DC coupled transistors to provide a voltage gain of 60 dB (as in 2.2.3). The output of the pre-amplifier is capacitively coupled to a unity gain operational amplifier buffer which is DC coupled to the transponder tuned listening amplifier. The resistor coupling the stages sets the overall gain of the transponder and thus the minimum signal sensitivity and maximum range obtainable from the transponder. The tuned stage is of the active biquadratic design described in Siliconix Application Note AN74-6. As in Section 2 the filter is voltage sensitive and so batteries with stable discharge characteristics are used. It uses three operational amplifiers and is tuned by varying two (chosen for convenience of tuning to be made up of series pairs) resistors and two capacitors. The practical operational amplifiers chosen are the micropower Siliconix L144BP containing three on one chip. To obtain the required slew rate a set current of 250nA is required, obtained using a setting resistor of 470KΩ. The phase compensation capacitor necessary (C_C) is 100pF. The gain of the filter at 10 kHz is 36 dB, the Q is 35, and the roll off is 18 dB at 9 and 11 kHz. The tuned circuit current consumption is 300μA. The circuit also requires a mid-range voltage reference point which is obtained using two large R-C circuits in series.

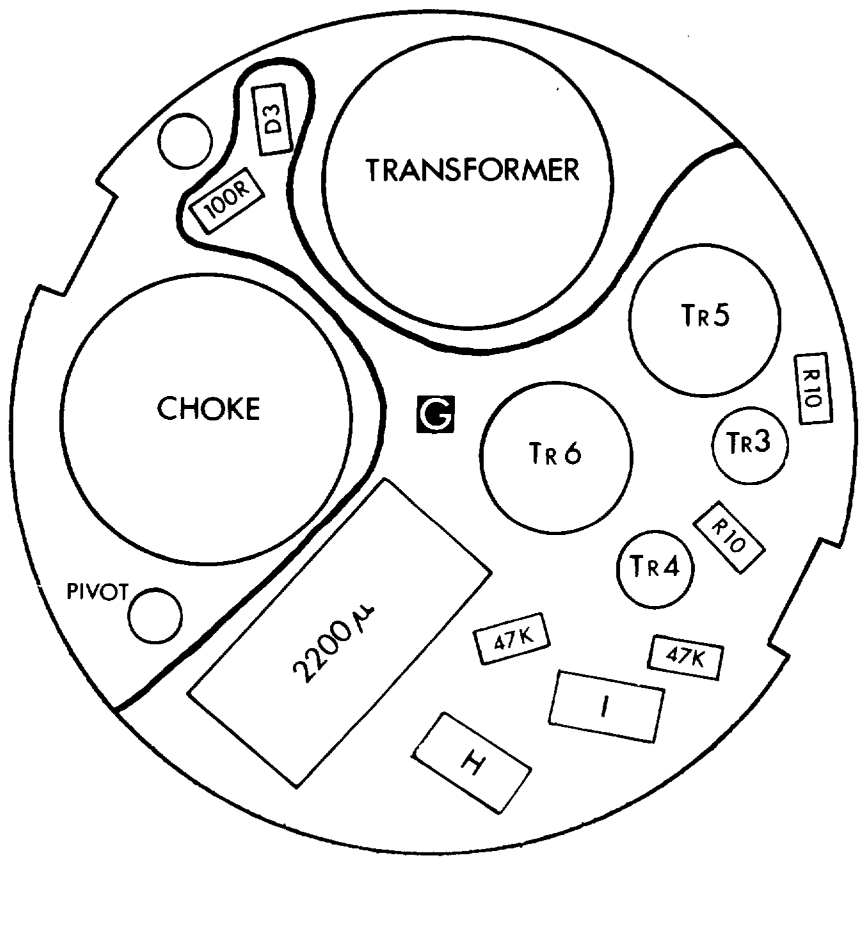
4.2.3 The detector The tuned stage output is rectified, integrated and referred to an operational amplifier voltage comparator. This comparator is set to ignore the quiescent DC bias point plus a margin allowing for noise. This point also therefore controls noise immunity and obtainable range.

The output of the comparator is slow switching compared to logic circuitry, does not switch fully rail to rail and can move slowly between high and low voltage

FIGURE 19. LIGHTWEIGHT TRANSPONDER CARD LAYOUTS



CONTROL BOARD

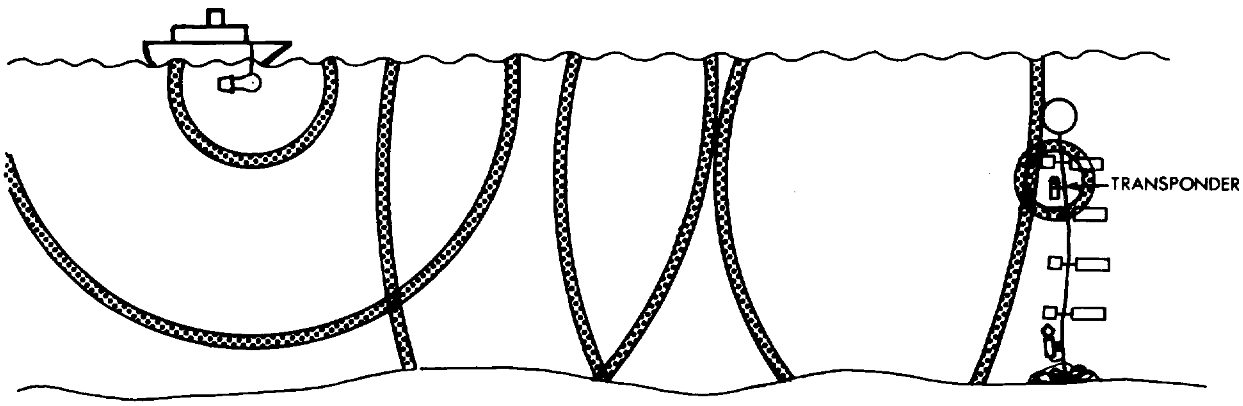


POWER BOARD

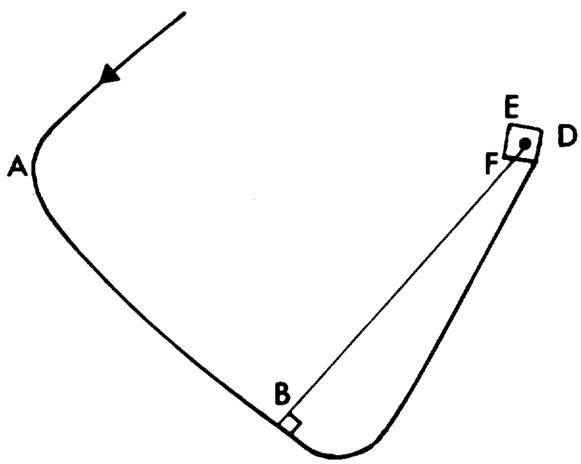
states in the presence of high noise. This sort of input can cause multiple switching and even linear operation causing high current drain in CMOS circuits. This uncertainty of operation can be largely eliminated by using a NAND gate circuit to compare the fluctuating level at one input with the fixed rail at the other. This performance can be further improved using a Schmitt trigger NAND with its fast switching speed and the large threshold hysteresis exhibited by the input gates. Therefore in the transponder a Schmitt trigger NAND is used as the detector. This drives two further Schmitt NANDs arranged as a latch. The latch is reset by a crystal clocked binary counter. Thus as soon as the comparator output exceeds the Schmitt switching threshold, the latch is set and further operation of the comparator is irrelevant until the latch base has been reset by the counter.

4.2.4 The control logic The circuitry from the Schmitt detector on is mainly digital logic and heavily dependent on the 320 kHz crystal stabilised clock; the clock circuit is as described in 3.2.2. The output is buffered and used to drive a free running 12 stage binary counter (B) which in its turn drives a second free running 12 stage binary counter(C); these two counters form the units primary timing chain. Output '4' of B is 20 kHz and provides the carrier frequency as described for the Acoustic Beacon Type H (3.2.5). One, two or three outputs from C are mixed using a 'diode-OR' configuration and used to provide the reference rail for the detecting Schmitt NAND; if any output is high pulses can be detected but not if all are low: the normal configuration uses outputs '9' and '10' which gives approximately 3 seconds silence every 12 seconds. A third 12 stage binary counter (D) can be driven from any output of B or C; this counter is enabled by the detector latch circuit; two of its outputs are mixed using a NAND gate and used to reset the detector latch, also disabling itself; this is used to control the dead time of the transponder. D is normally clocked from output '12' from B, and its outputs '4' and '7' are used to give a dead time of approximately 0.92 seconds. A decade counter (E) is also reset by the detector latch; this is used to produce the pulse envelopes for transmission. The decade is clocked from a suitable output from B or C; the pulses produced are as long as the period of the clocking frequency. The decades last output '9' is used to disable itself; it thus produces one burst of pulses every time the detector latch operates. The decade is normally driven by output '10' of B giving pulse lengths of 3.2 milliseconds (ms). Output '0' can be of any length from 0 ms to 3.2 ms as the decade is being clocked by a free running oscillator and the detected pulses are not synchronised with it; this is the basic reason for the jitter observable in normal operation. Because of the variation in pulse length of output '0', output '1' is

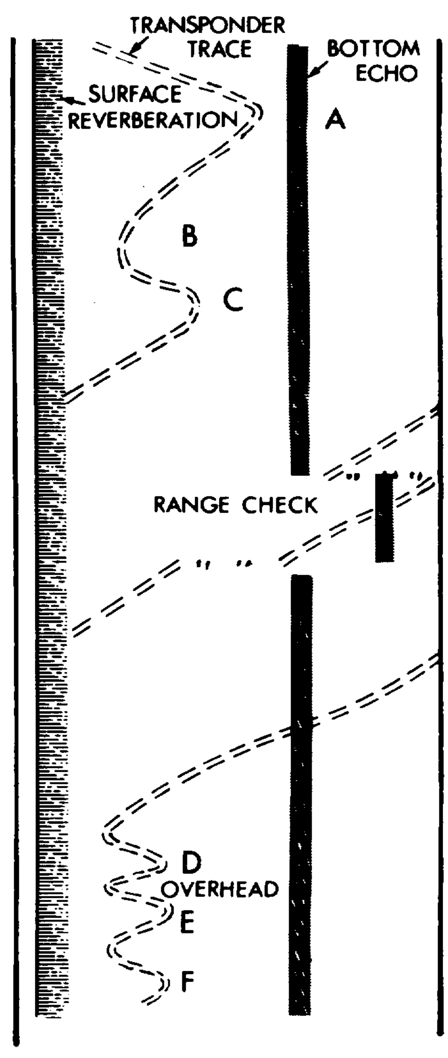
FIGURE 20. OPERATIONAL USE OF A TRANSPONDER



SHIPS TRACK



FACSIMILE PICTURE



Range Check

Transponders may be used to obtain a direct range by timing the interval between an interrogation pulse and the transponder's reply. When using an interrogator synchronised to a facsimile recorder display ranges exceeding one sweep may be identified by changing the sweep rate by a known percentage; the received trace will be displaced by that percentage of a sweep for every extra sweep period to be added to the apparent range.

normally used for first replay and then any of outputs '2' to '8' to code the reply, identifying the unit. If the uncertainty in range due to jitter causes a problem output '0' can be used and its leading edge will be jitter free BUT its pulse length will vary from 0 to 3.2 ms. The two pulses chosen are mixed using a 'diode-OR' and used to gate the carrier and pulse power amplifier drive as in 3.2.5.

4.2.5 Output pulse power amplifiers The circuitry is as described for the Acoustic Beacon Type H (3.2.6). The standard printed circuit can be used for either type and will accommodate the ceramic ring choke and transformer on its card.

4.3 Using Transponders

4.3.1 A shallow water limitation This transponder and its derivatives have been designed for oceanic use: the power levels and sensitivity may well be an embarrassment at depths of less than 100 metres; the ten kilohertz component of some ship noise may well interrogate the standard unit and in calm conditions the reply will be audible to the unaided ear over a wide area (a radius of 500 metres or more).

4.3.2 Interrogation At deployed depths greater than 500 metres (m) the standard IOS Mark III PES system will give adequate operational ranges; the mushroom transducer at 500 m and 5000 m should give ranges of at least 1000 m and 10,000 m respectively; the ceramic ring transducer at 500 m and 2000 m should give ranges of at least 4000 m and 8000 m respectively. At shallower deployed depths (a) the sea unit should employ a ceramic ring transducer and (b) the shipborne system may well require a towed ceramic ring transducer used in conjunction with the interrogation facilities of the standard Deck Control Unit Mark IV or a specially modified Deck Control Unit Mark III (described in Parts 2 and 4 of this series); obtainable ranges should be of the order of 8000 m at 500 m depth and 5000 m at 200 m, but this may well be reduced by propagation conditions (as discussed in Part 1 of this series).

4.3.3 Location and ranging When used for the location of moored instrument packages the basic technique is as described for beacons in Part One of this series but with the advantage of being able to work out the exact range of the transponder. The simplest way of obtaining the range is to fire just one interrogation pulse, time the arrival of the response pulse and multiply this by the speed of sound in water remembering that it is a two way path. However, this is often not the easiest or even a practical method. Transponders are normally

FIGURE 21. BATTERY CHOICE FOR DEEP SEA WORK.

Batteries for use in the deep ocean have to perform well at low temperatures. Instruments operating independently of a ship must normally be small and light as pressure cases and buoyancy are expensive. Instrumentation deployed for long periods require batteries with good storage characteristics. Instruments operated on a wire permanently attached to the ship allow more freedom of choice but as the ship environment is always hazardous the instrument must be safely handleable. N.B. All high capacity batteries are potentially dangerous.

The 'ideal' battery will vary with the application but in general the most versatile size is the 'D' cell. This is also a convenient size for a comparison of the properties of the cell types in common oceanographic use.

	PRIMARY CELLS				SECONDARY CELLS	
Property	Lithium/ Sulphur Dioxide	Mercury^{x}	Alkaline/ Manganese	Zinc/Carbon (HP2)	Nickel/ Cadmium	Lead/Acid (Gel)
Nom. O.C.V.	3.0	1.35	1.5	1.5	1.2	2.1
Unit Price	£4.78	£4.30	49p	29p	£2.95	£2.89(25+)
†Capacity(Ah)	10	14	10	5	4	2.5
Storage to 80% Cap(20°C)	>10 yrs	>3 yrs	>3 yrs	9-12 mths	1-2 wks	3 yrs
†Cap at 0°C	95	80	80	80	95	80
†Load V	2.8	1.2	1.4-1.0	1.5-0.9	1.2	2.1-1.9
†End Point V	2.6	1.1	0.9	0.8	1.0	1.8
†WH/£ at 0°C	5.62	3.13	19.6	16.7	154*	139*
†WH/kg at 0°C	315	97	73	63	25	22
†WH/cm³ at 0°C	0.50	0.31	0.18	0.11	0.08	0.065

Nom. O.C.V. - Nominal Open Circuit Voltage, Price - 100+ at October 1981.

†Properties at 50 hour discharge rate, WH - Watt Hours, x - only certain constructions.

*For 100 cycles BUT NOT INCLUDING charger and electricity costs.

interrogated at a precisely timed rate synchronised with a precisely correlating display. A step change of rate can be simultaneously introduced to both interrogator and display; the interrogator and reply pulses in the water at the time of the change will continue at their original time spacing; when received at the ship these pulses will be seen to step across the display until the first of the pulses at the new rate arrives; the pulses will then once again correlate. The displacement on the display will be directly proportional to the range of the transponder; Figure illustrates a typical example of display appearance and the simple calculation involved. This technique is easily used if a Mark III or Mark IV Deck Control Unit and a compatible facsimile recorder is available.

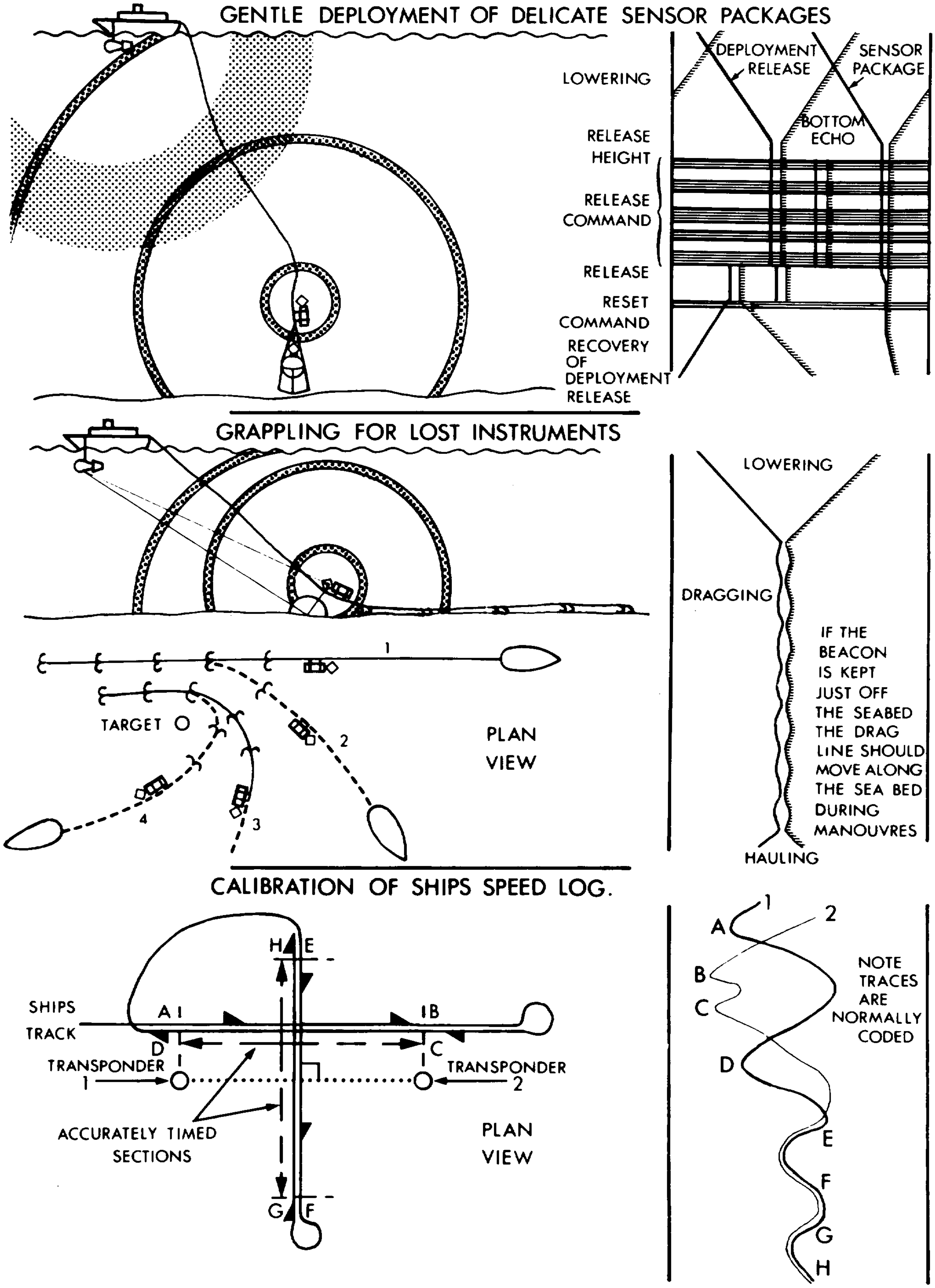
When using transponders or beacons for location and ranging, results must be interpreted within the framework of the three dimensional nature of operation (normally simple geometry); if accurate scientific measurement is required refraction and multipath effects must also be considered.

When a transponder is a target for dragging a beacon on the drag line may be used to interrogate the target and interpretation is straightforward and useful. If a beacon is a target for dragging, the use of a transponder on the drag line is not recommended as interpretation is not as straightforward or very useful.

4.4 Physical Arrangements

The standard lightweight 10 kHz transponder uses two circular electronic cards and seven 10 ampere hour (AH) lithium batteries which enable it to listen for two years and reply to continuous interrogation for more than 120 days; this package size is 18 cms long and 11.5 cm diameter. Versions using 1.1 AH batteries powering the transponder for 60 and 12 days respectively have been made; this package size is only 10 cms long and 11.5 cms diameter. Recoverable and long life versions can be produced but obviously require longer pressure cases.

FIGURE 22. SOME UNUSUAL APPLICATIONS

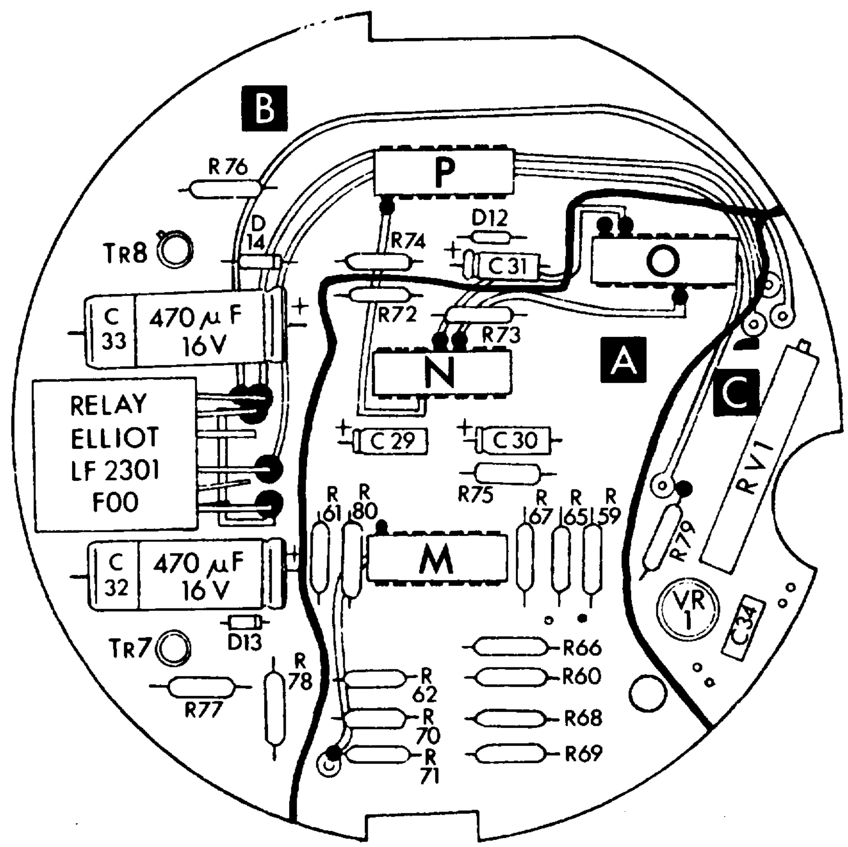


5. SPECIAL VERSIONS

5.1 General

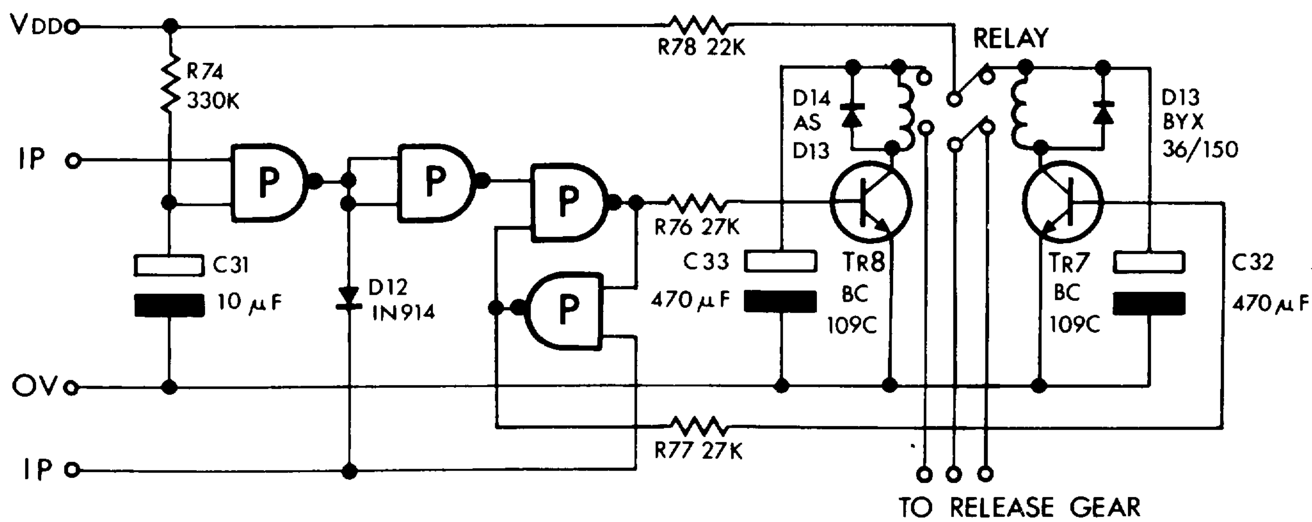
The wide range of scientific investigations carried out by the IOS result in the application of many instrument systems to tasks not in the original specification. The Command and Monitoring System was designed with this in mind. Many units have been adapted for 'one-off' applications and several variants have themselves become standards and are described in other parts of this section. Some successful one-off applications of sea units have been: the use of a standard CR200 unit to release gently onto the sea bed a sensitive instrument package from the end of a lowering warp at a depth of 5000 metres; the use of a standard beacon to monitor a buoyancy sphere for leakage during a test to destruction - the sphere was 120 cm in diameter and imploded at 1000 metres without premature leakage, badly distorted the beacon support frame but did not damage the beacon; the use of magnetically operated reed switches with standard beacons to monitor the mechanical operations of a wide variety of samplers; use of standard beacons to indicate film wind on and flash operation with camera systems; the use of two standard transponders buoyed to float 10 metres below the sea surface one kilometre apart to act as an acoustic base line for ships log (speed) calibration.

FIGURE 23. NET MONITOR RELAY CARD AND CIRCUIT.



SECTION **A** IS THE SAME AS SECTION **A** – RELAY CARD B – FIGURE 6.

SECTION **B** IS THE LATCHING RELAY DRIVE CIRCUIT.

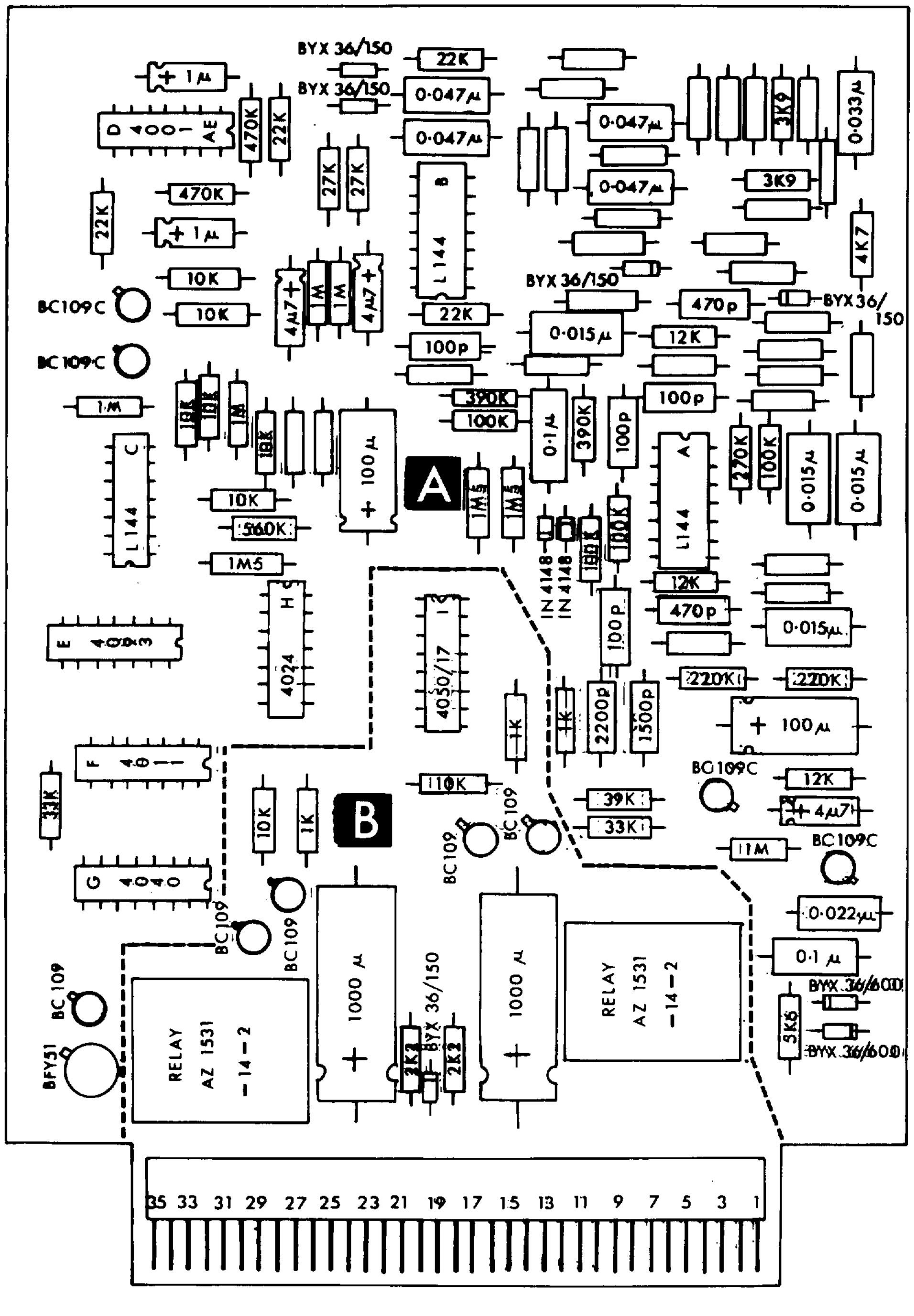


SECTION **C** IS THE VOLTAGE REGULATION CIRCUIT.

5.2 Net Monitor Command Cards

The pressure cases used for these instruments allow a slightly larger diameter card to be used; this has allowed the component spacing to be slightly relaxed and the diode detectors to be included on the receiver card (also reducing the inter-wiring by one wire). The receiver card (Figure) has the same circuitry and basic layout as in Section 2.2 plus the two diode detectors. The power supply is 5.0 volts provided from the 10 volt logic supply by a voltage regulator. The relay card uses the same op amp detector as described in Section 2.3.2 but the logic and relay are considerably different. The relay used is a two pole two way latching type; the two channels being used to latch and relatch the relay alternately; the two channel frequencies are always centred on 480 Hz and 500 Hz. The logic operates the relay after one unit of detected signal (approximately 1½ seconds); the other channel cannot relatch the relay until the relatching capacitor is charged; the power supply to the two latching capacitors is switched by one set of contacts on the relay. The logic is also designed to automatically set the relay to the same state every time it is powered up. The circuitry is more fully described in 'Remote Monitoring Systems'.

FIGURE 24. PUBS/OBS COMMAND CARD



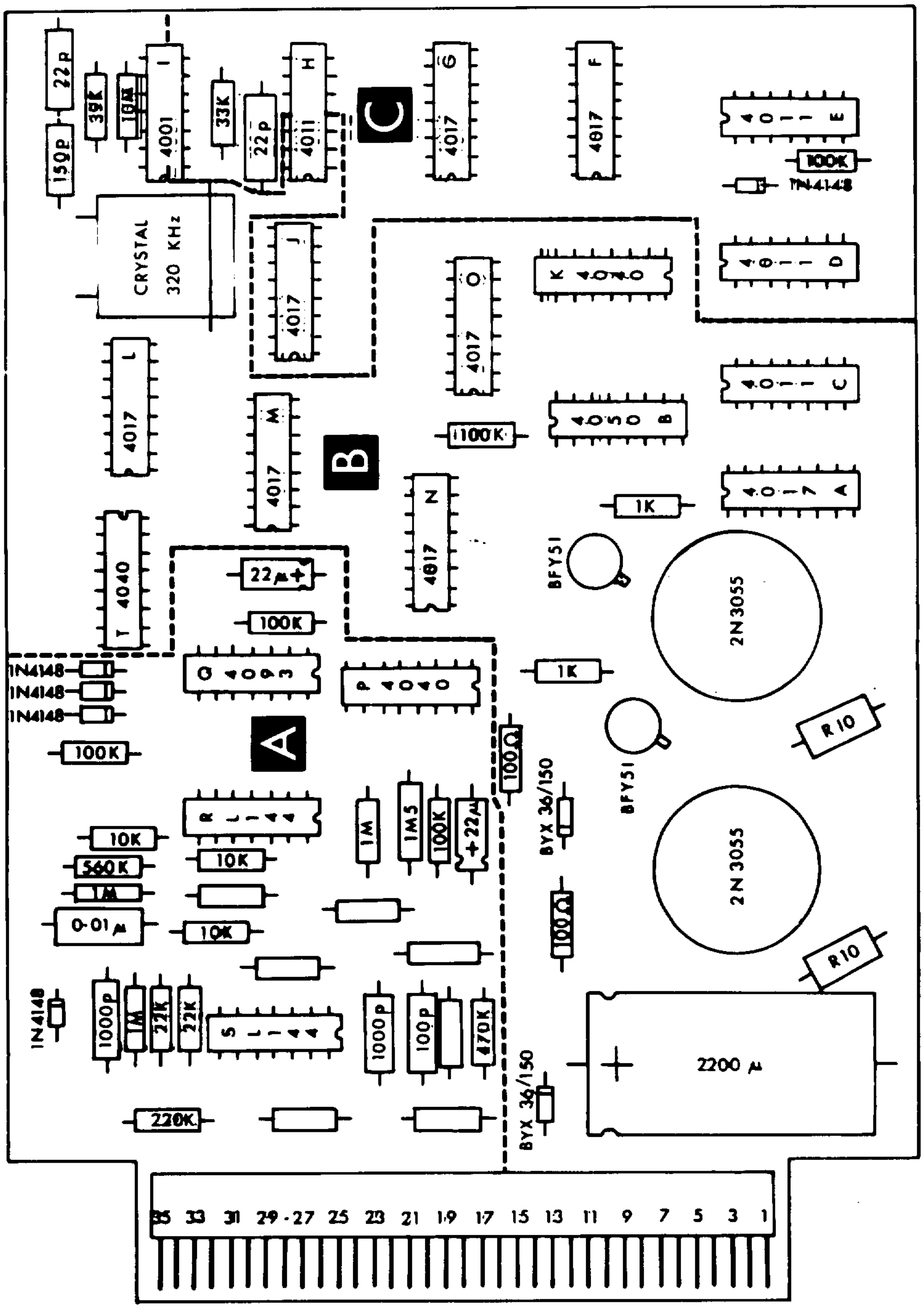
FOR COMMENTS SEE FIGURE 26.

5.3 OBS/PUBS/BENCAT (Ocean Bottom Seismometers, Pop-Up Bottom Seismometers, Benthic Current and Temperature Recorder)

These three instrument systems each make use of one .75 cm internal diameter sphere as main electronic housing and buoyancy package. The acoustic transducer used is a ten cm (4") mushroom design mounted in the top of the sphere; all three systems have been designed for deep ocean applications. The acoustic location and recovery (monitoring and command) electronics were designed with all three applications in mind although minor differences were required. The electronics combine the release, beacon, and transponder circuits on two 13 cm by 8 cm plug in cards, and is matched to the acoustic transducer by a standard transformer mounted on the main chassis close to the two boards. The electronics has been aligned to make use of lithium based cells (Duracell design)(receiver voltage 5.8V) incorporated in the main system battery pack (but as isolated supplies). Other battery systems could be used but some realignment would be necessary.

5.3.1 Command card The receiver and operation of functions are combined on this card. The receiver circuitry, layout and alignment are as in Section 2.2. The operation of functions is basically as in Section 2.3, but with several important detail changes: channel detection differs by discharging the detecting capacitors using discrete transistors (BC109C) rather than CMOS gates (4016). Mooring location is achieved by the switching on of the power supply to the second card by the operation of either channel as in Section 2.3.3; the common (320 Hz) channel switches this card to a 'transponder' mode of operation and the other (release) channel switches this card to the beacon mode; the logic arrangement to achieve this differs by using 'Schmitt trigger' type NAND gates (4093 rather than 4011) to avoid multiple operation due to the slow switching speed of the detector monostables; the second card is switched off as in Section 2 but the pulses counted are not the output pulses but a constant frequency generated on that card. Mooring release employs the basic technique described in Section 2.3.4 but detail changes have been made to increase security and accommodate differing applications; the relay operating binary counter is not clocked directly by the release channel monostable but after this output has been shaped by two Schmitt NAND gates - this avoids multiple clocking of the counter by a slowly switching monostable; the relay counter is not reset by the 'time out' counter but directly by the transpond/beacon channel latch - thus operation of the transpond command channel automatically resets and disables the relay counter; the BENCAT and some of the OBS require sequential operation of two relays; this is achieved by replacing the buffer chip (4050) used to drive the transistors, charging the capacitor and

FIGURE 25. PUBS/OBS TRANSPONDER AND BEACON CARD



FOR COMMENTS SEE FIGURE 26.

firing the relay by a decade counter chip (4017); the outputs of this chip are buffered and so capable of driving the transistors unaided; the clock input is taken from output '4' of the relay counter, the reset is tied to the relay counter reset, and the enable line is tied to the 0 volt rail; output '1' is used to charge capacitor 1, output '2' to fire relay 1, output '3' to charge capacitor 2 and output '4' to fire relay 2; both versions are accommodated on the same card layout.

5.3.2 Transponder/beacon card This card uses variants of the beacon described in Section 3 and the transponder described in Section 4 for function monitoring and location: the oscillator and timing circuit differs from that described in 3.2.2 by using NOR gates as oscillator inverter and buffer, and using a 12 stage binary counter (4040) as primary divider rather than the seven stage counter (4024). Pulse generation is different to both standard versions: generation is by mixing output pulses from two decade counters; the first decade is driven by 500 Hz derived from the beacon timing chain and thus its outputs are of 2 millisecond duration; the second decade is driven from the carry-out of the first decade, its outputs being 20 milliseconds duration; the tenth output of the second decade is applied to the 'enable' inputs of both counters thus after 180 milliseconds operation of the counters stops; control of operation is via the reset inputs of both counters; when the transponder latch is reset or the beacon trigger pulse occurs the reset line goes low allowing the counters to run until stopped by the 'enable' line; output pulses are obtained by mixing 2 ms and 20 ms pulses using NAND gates; two pairs are used and thus separations of from 2 ms to 178 ms are theoretically possible to enable identification of individual units; practically 20 ms is an easily discernible step interval allowing 8 identifying codes; BENCAT also uses the 'diode-OR' mixing technique to produce extra pulses indicating correct deployment, excessive tilt, and sphere leakage. Pulse conditioning and the pulse power amplifier are as standard (Sections 3.2.5 and 3.2.6). Whether the system operates as a transponder or a free running beacon is controlled by a single input being high or low; this input then by a system of NAND gates enables the pulses triggered by the beacon or transponder circuitry and a suitable carrier frequency. As an upward looking mushroom transducer is used operation at 10 kHz while suitable for the beacon mode could provide self locking problems in the transponder mode. The beacon carrier frequency base (20 kHz) is to drive the beacon timing chain; the transponder carrier frequency is derived using a decade divider, a NOR latch and two NAND gates; the decade counter is driven by the 320 kHz, its xth output sets the NOR latch which enables and NAND gate; the decade's yth output can then pass through the NAND gate and reset the latch and

FIGURE 26. PUBS/OBS VARIATIONS FROM THE STANDARD CR 200

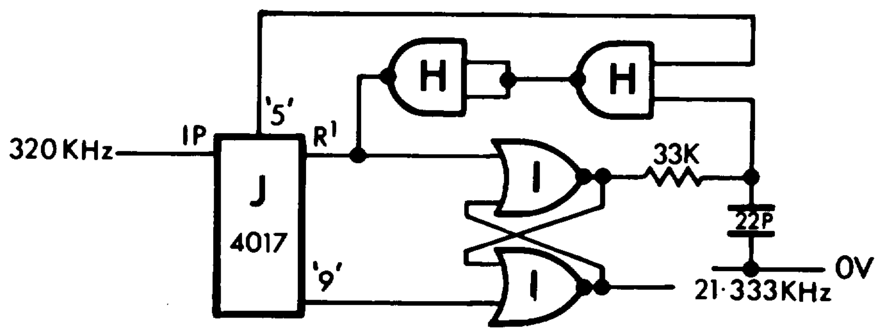
TRANSPONDER/BEACON CARD

A CIRCUIT AS SECTIONS **B** AND **E** OF TRANSPONDER CIRCUIT (FIGURE 18)

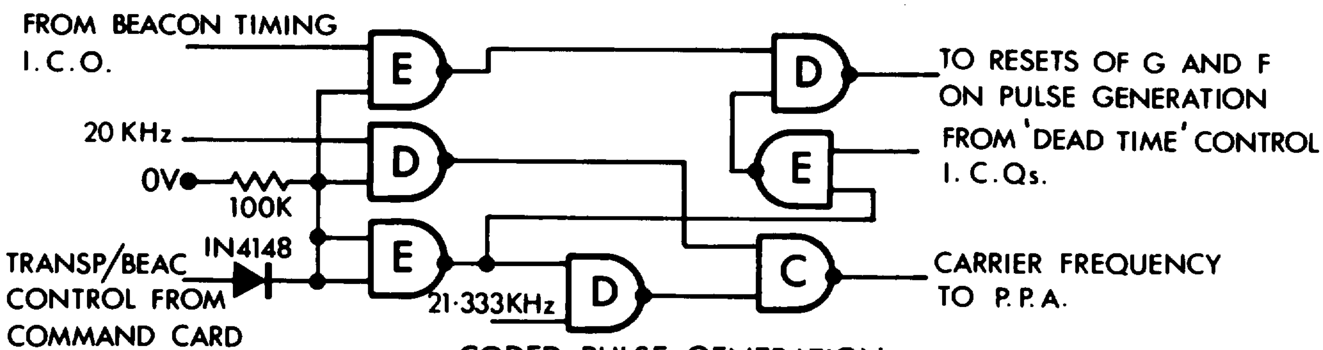
B CIRCUIT BASICALLY AS SECTIONS **A**, **B**, **C**, **E** AND **F** OF CR200 RELEASE BEACON (FIGURE 12). THE MAIN DIFFERENCE IS THE USE OF A 'NOR' TYPE INVERTER IN THE 320KHz OSCILLATOR CIRCUIT.

C THE TRANSPONDER REPLY FREQUENCY GENERATION, TRANSPONDER OR BEACON CONTROL CIRCUIT, AND THE CODED PULSE GENERATION ARE PECULIAR TO THESE APPLICATIONS.

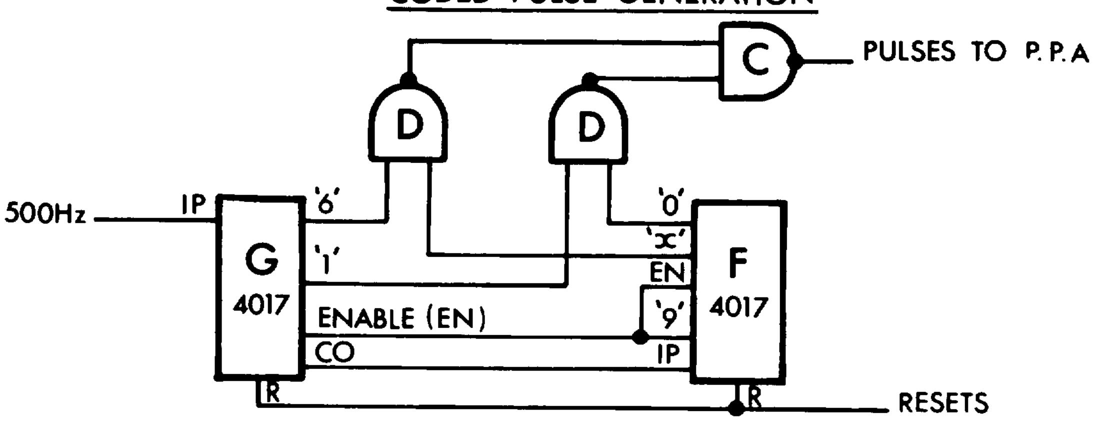
TRANSPONDER REPLY FREQUENCY GENERATION



TRANSPONDER OR BEACON CONTROL



CODED PULSE GENERATION



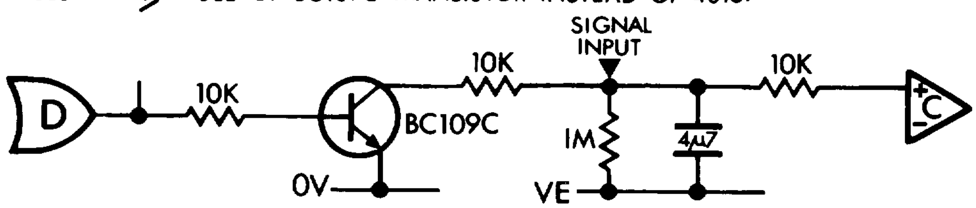
the decade counter; because the latch resets faster than the decade counter its output enabling the NAND must be slowed to allow the decade to reset; the respond carrier frequency base selected is 21.333 kHz (10.666 kHz), this is 320 kHz divided by 15 and is achieved by making the x output '9' and the y output '5'. The rest of the transponder circuitry is as described in Section 4; the initial input signal comes via a capacitor from the output of the receiver preamplifier; the normal interrogation rate is two second period so a dead time of 1.9 seconds is normally used; the anti-lock total disablement period is normally 5 seconds in 20 or 40 seconds.

FIGURE 26. CONTINUED

COMMAND CARD

A CIRCUIT AND LAYOUT BASICALLY AS CR200 BOARD **A** AND BOARD **B** SECTIONS **A**, **B2**, AND **D** (FIGURES 4, 6, AND 7).

MAIN DIFFERENCES — 1. USE OF BC109C TRANSISTOR INSTEAD OF 4016.



2. USE OF 4093 (SCHMITT NANDS) INSTEAD OF 4011 — I. C. E.

B CIRCUIT SIMILAR TO BOARD **B** SECTION **C** BUT EQUIPPED TO OPERATE TWO RELAYS SEQUENTIALLY IF REQUIRED.

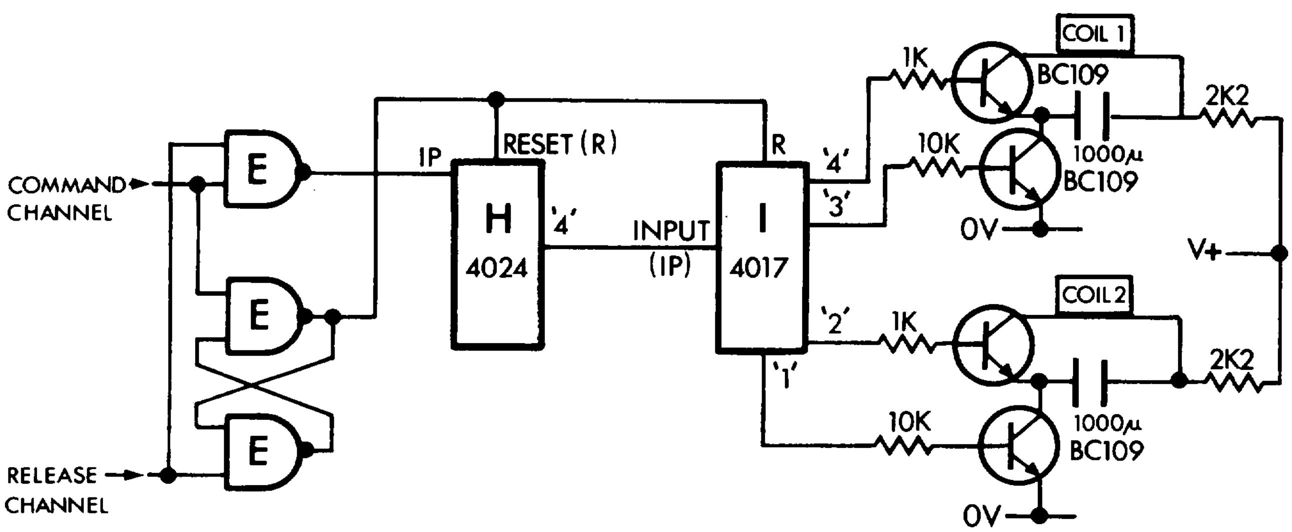
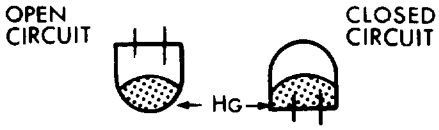
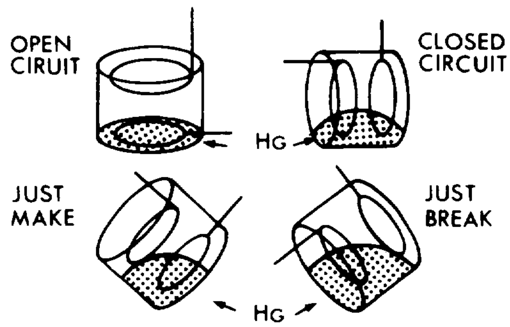


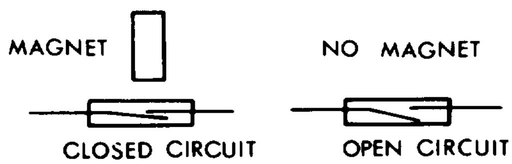
Fig. 27 Discrete Sensors.



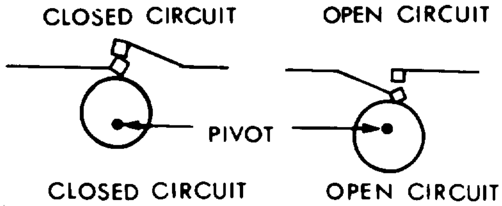
SIMPLE MERCURY (HG) SWITCH
ONLY RELIABLE FOR COMPLETE INVERSION



MORE USEFUL MERCURY SWITCH MAKE AND BREAK ANGLES ARE ACCURATELY DETERMINED BY RING SPACING AND MERCURY CONTENT.

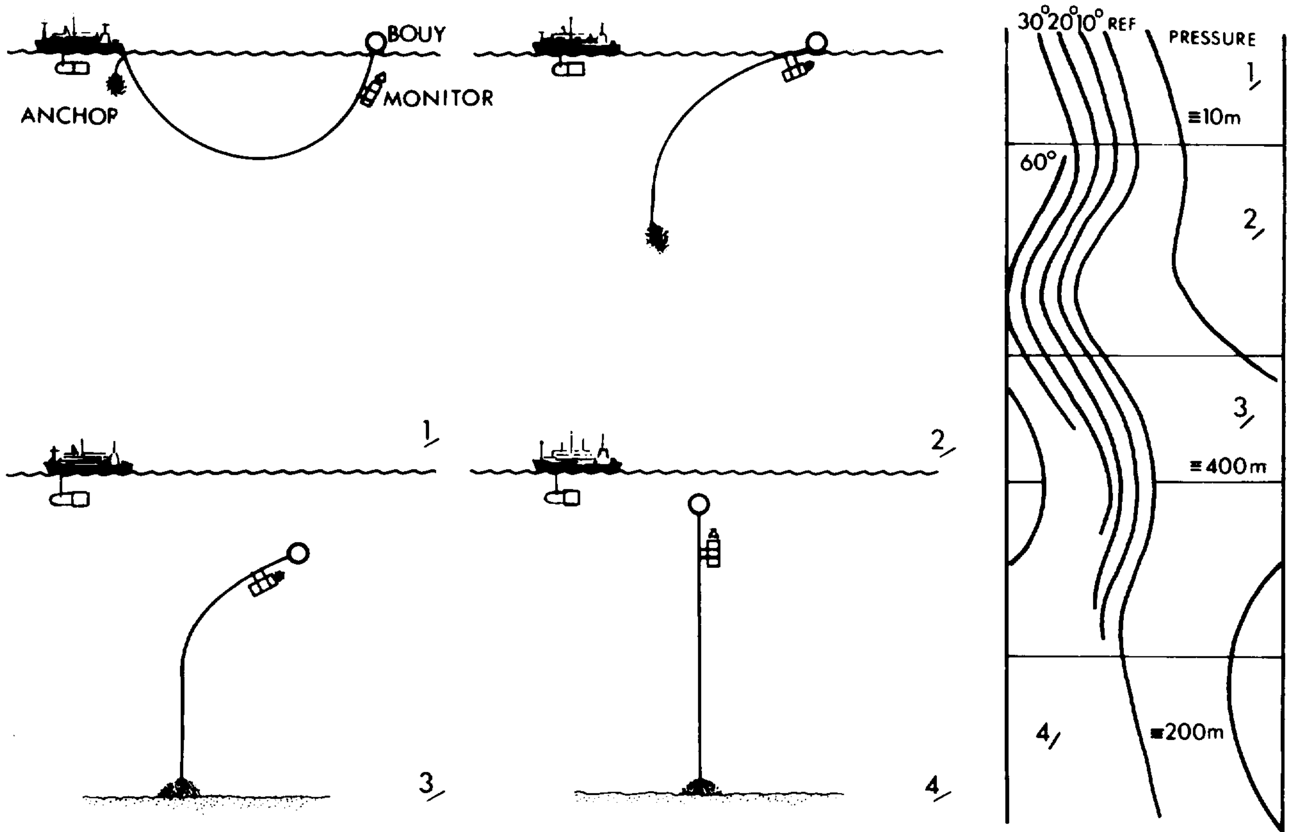


MAGNETICALLY OPERATED REED SWITCHES ARE FREQUENTLY OPERATED THROUGH NON-MAGNETIC PRESSURE CASES.



CAM OPERATED SWITCHES USEFUL FOR MONITORING MOTOR OPERATION SUCH AS CAMERA FILM WIND-ON.

A BUOY FIRST MOORING LAY MONITORED USING TILT AND PRESSURE



5.4 Tilt Monitors

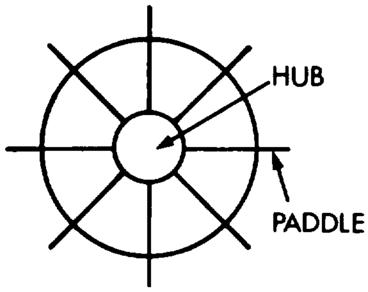
Knowledge of the orientation of sampler systems with respect to gravity vertical is frequently very useful and in many cases essential to their correct operation. Applications may be considered as operating in two or three dimensions and requiring continuous or stepped measurement of angle. Asymmetric towed systems (Rectangular Midwater Trawls (RMT) and Benthic sled (BN) samplers for instance) can usually be adequately described by tilt sensors operating in two dimensional planes. Most other systems require three dimensional sensors.

Two dimensional applications: The RMT net sampler system presents a different mouth area (and therefore samples a different volume of water) at different speeds through the water; the effect is caused by drag and is not effectively modelled; the sampler was fished at a speed and duration that optimised sample quality with quantity, but with filtered volume relatively uncertain; this uncertainty was resolved by using continuously variable two dimensional sensors in several positions on the side of the net at several speeds through the water; the sensor used was a damped pendulum operating a potentiometer which varied the frequency of an oscillator (all contained in a pressure case); this was telemetered to the ship by a net monitor (described fully in 'Remote Monitoring Systems'). A two dimensional sensor that could have been used produces a voltage proportional to tilt from a glass phial containing two electrodes and half full of a resistive electrolyte; this sensor requires A.C. excitation and is more difficult to encode. The BN samplers have a rigid oblong structure and will normally only operate one way up; they normally descend with one axis nearly vertical and sample with that axis nearly horizontal; the sensors used normally consist of glass phials penetrated by two straight electrodes and containing a small amount of mercury; the sensors are frequently mounted in the monitoring beacon to indicate when the beacon is inverted and horizontal; the beacon is then carefully mounted in the sampler such that the beacon's orientation faithfully matches that of the sampler. Telemetry is by the presence or not of extra beacon pulses gated by the sensors.

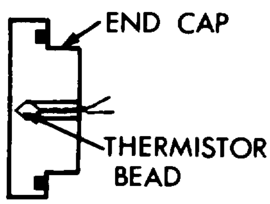
Three dimensional applications: At present there are three types of sensor available: one continuously variable and two variations of discrete. The continuously variable type uses a damped pendulum and two potentiometers in an inverted 'Joystick' configuration; the potentiometers may be monitored separately as in the two dimensional case giving a two component description or resolved to give a single reading. The discrete types use mercury and two electrodes in a glass phial; they differ in electrode shape and mercury content. One type uses a central straight electrode and a concentric ring electrode; the angle at which

FIGURE 28. CONTINUOUSLY VARIABLE SENSORS

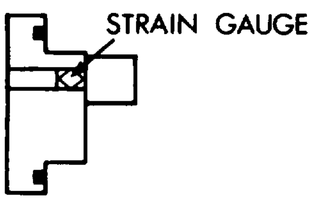
THREE SENSORS USED IN A BENTHIC SLEDGE SYSTEM



DISTANCE RUN IS MEASURED USING A 360° POTENTIOMETER MOUNTED IN THE HUB OF A PADDLE WHEEL ATTACHED TO TO THE SIDE OF THE SLEDGE.
(VOLTAGE DIVIDER TYPE)

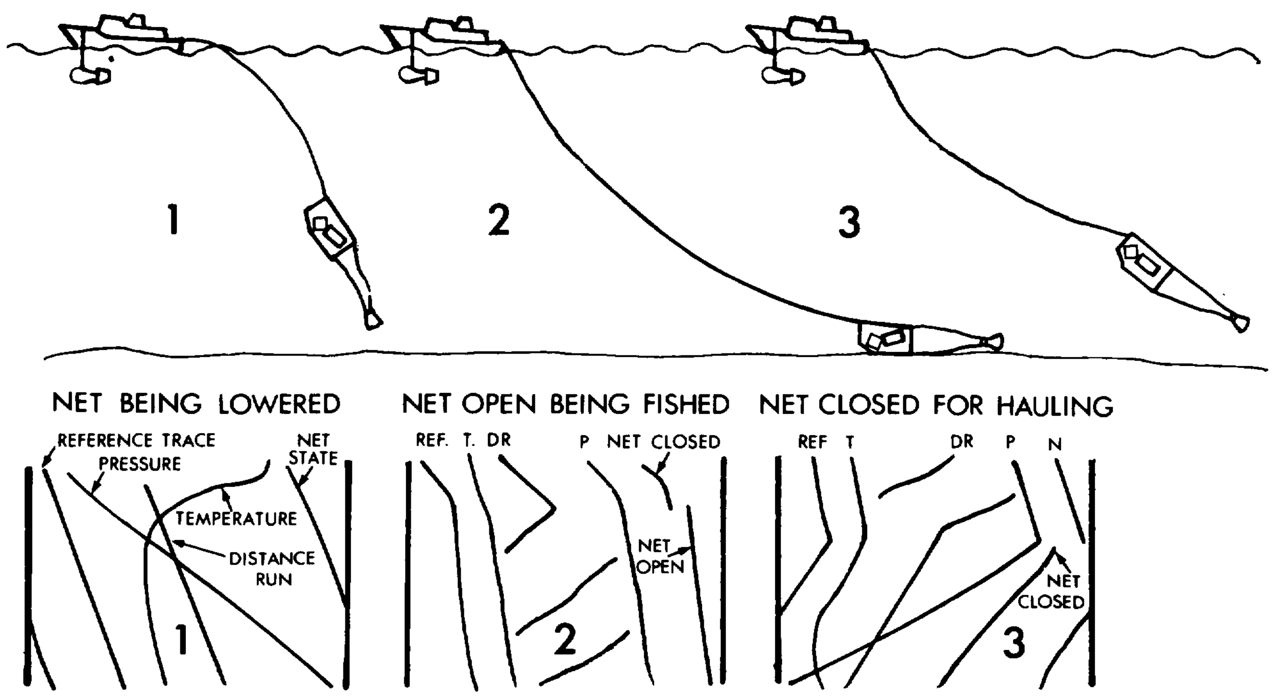


TEMPERATURE IS MEASURED USING A TEMPERATURE VARIABLE RESISTOR (THERMISTOR) MOUNTED IN THE NET MONITOR END CAP.
(VARIABLE RESISTANCE TYPE)



PRESSURE IS MEASURED USING A STRAIN GAUGE BRIDGE MOUNTED THROUGH THE NET MONITOR END CAP.
(VARIABLE VOLTAGE TYPE)

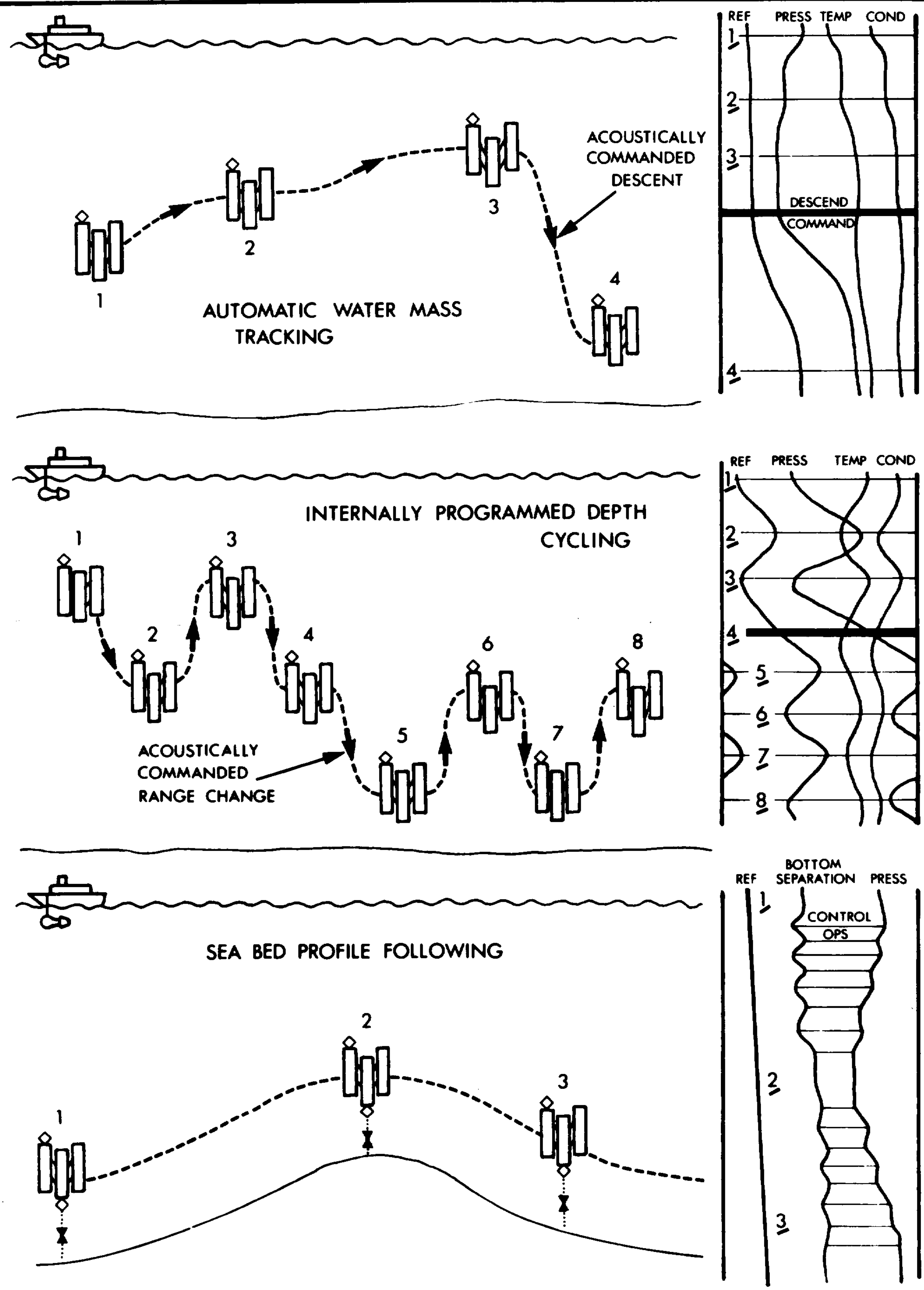
OPERATION OF THE BENTHIC SLEDGE SYSTEM



electrical contact is made depends on the amount of mercury; the drawback with this type is, if the designed contact angle is greatly exceeded contact is broken, an ambiguous indication is made, and break angle is not consistently related to contact angle. The second type is designed to overcome this problem; two ring electrodes of identical size are used; contact angle is controlled by electrode separation; break angle is the mirror image of contact angle (reflected in the horizontal plane); telemetry is by the gating of extra pulses (one per sensor) and commonly used values are (to the vertical) 5°, 10°, 15°, 20°, 30° and 60°.

These sensors have been used singly or in various combinations to measure: the operation of symmetrical towed samplers (rock dredges, grappling lines); the orientation of free standing bottom samplers and current meters; the integrity of moored instrument systems (if a command release at the bottom of a mooring is tilted more than 30° the mooring has broken); and a variety of one-off applications.

FIGURE 29. NAUTILUS FLOAT-A CONTROLLABLE BUOYANCY VEHICLE



5.5 Multifunction Command Units

Several deep ocean instrument systems have required remote control of more than the two functions described in Section 2. A variety of techniques are possible to perform multiple functions depending mainly on the degree of independence and speed of response required.

The simplest technique is to use either of the standard channels to initiate a timer (or timers) which then perform the desired functions. If more control is required but the operations are sequential (as in Bencat, but also incorporated into a circular card version), one of the standard channels can be used to operate the functions in proportion to the length of time signal is received by that channel. If totally independent control of each channel is required additional command channels may be used; this option requires buffering of the discriminated signal and uses up what could be an inconvenient number of command channels (has been used in the prototype Nautilus float system). An alternative and potentially more versatile technique for independent operation of functions has been investigated (and may well be applied in operational Nautilus float systems); the technique uses two standard command channels but first operation of one switches on timing and decoding circuitry; the command signal then alternates between channels in a precoded manner; the decoding circuitry then analyses the minimum time required for identification of a command channel to overcome propagation problems is 5 seconds (one bit) and the message length used has been 60 seconds (12 bits); this has been used as a 6 bit binary code with repeat confirmation - a maximum of 64 useable function commands.