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Natural Environment Research Council

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*ABSTRACT*

The results of trials carried out on RRS *Discovery* during mooring deployments in April 1993 are presented. Ranging trials were carried out on acoustic releases deployed at between 1500m and 5900m, using the PES fish and the MORS ceramic ring transducers. The performance of the system is assessed as adequate and various recommendations for future operations are made.

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**Acoustic Trials of the MORS RT661 and TT301**

## 1 Introduction

Eight moorings were deployed as part of the SWINDEX experiment from *Discovery* in the Southern Ocean in March and April 1993 in a range of depths from 1700m to 5900m. They were planned to be recovered after 18-24 months. Two types of acoustic release were available, the MORS RT661 (reference 7) and the IOSDL CR200. Each mooring was deployed using an RT661 doubled up with a CR200 as the acoustic release package. The CR200 normally fires a "pyro" (reference 5), an IOSDL-designed explosive device that operates a mechanical release mechanism. The RT661s have a motor-driven release hook, but those bought by IOSDL had been modified to allow them to fire a pyro as well.

This was the first time IOSDL had used RT661s in deep water, and a number of trials were conducted to assess their acoustic performance. The objectives of these trials were to find at what depths and slant ranges the RT661s can be commanded from, at what range the pinger can be heard, whether there are any irregularities in the signal strength due to the transducer characteristics and what differences, if any, there are between the various hardware configurations.

## 2. Initial Set-up

### 2.1.RT661

Nine RT661s were available; three were in their original ferallium cases, with their original ceramic ring acoustic transducers and six were in IOSDL hard-anodised aluminium pressure cases using Marine Acoustics Ltd. ceramic ring acoustic transducers. The ferallium cases had an entry in the end-cap for an XSG-type connector, to allow a pyro to be fired. All units were powered by six packs of three Lithium thionyl chloride 'D'-cells, with an IOSDL 15V Lithium manganese dioxide pinger battery as a pyro-firing pack. One of the RT661s in a ferallium case had the lifting lug and ring above the transducer removed, the other two were as originally supplied.

All nine units were set up to fire a single pyro using the motor drive supply, and were test-fired at their deployment depth. All of the units could operate in "pinger" mode, in which the RT661 transmits a 10kHz pulse at a repetition rate of precisely two seconds. This can be observed on any suitable facsimile-type display, such as the IOSDL waterfall display.

### 2.2.TT301

Two MORS TT301 deck units were available, the Marine Physics unit from IOSDL and a unit from

MAFF. The TT301 is designed to transmit and receive through its own dunking transducer, a ceramic ring. In this case a single element (PES transducer) from the echo-sounder fish was used by the TT301 through the "XDC" socket. This created a mis-match between the receiver and the transducer but this was not critical to the performance of the system and it is the system most likely to be used in the future on IOSDL cruises. The PES transducer has an impedance of about 2 kΩ compared with the 500 Ω of the ceramic ring, although there will be variations on the actual PES fish impedance due to the number of junction boxes, length of cable run and condition of slip rings on different NERC ships. The PES transducer has a working bandwidth of 8-12kHz, and IOSDL had specified the frequencies of the RT661s to fall within this range. A dunking transducer was also available, supplied as standard with the TT301 by MORS. This was used during some of the later moorings to obtain greater ranges when fixing the anchor positions.

The IOSDL TT301 has been modified and contains a Waterfall display receiver card. The input to this is via a transformer, and the "XDC" socket can be switched between the Waterfall display receiver card and the TT301 itself. There were some problems with command transmission, apparently due to problems with the battery pack, but in general it was able to transmit through the PES fish adequately. The receiver channel did not work at all, probably due to a faulty op-amp, Z2, in the channel filter.

The MAFF TT301 was used for ranging on the RT661s and to ascertain the sensitivity of the TT301 receiver. It transmitted commands and received acknowledgements through both the PES fish and the ceramic ring dunking transducer, again the main problems coming when the battery pack started to get low. All slant ranges obtained from the TT301 are quoted as uncorrected, assuming a constant sound velocity of 1497m/s, and were the result of the RT661 receiving a command and sending an acknowledgement pulse which was heard by the TT301.

## 2.3 Wire Tests

The RT661s were lowered as close to the proposed mooring depth as possible, attached to the CTD frame. The firing check was carried out using the MAFF TT301 and waiting for the reply from the RT661 in the conventional manner. It should have been possible to use the pinger mode to confirm the operation of the release command. When the "window" command is correctly received, the pinger is switched off, awaiting a further command. If no command is received after a fixed time (the "time-out" period) the pinger is switched back on. By waiting for the "window" command to switch off the pinger, and then transmitting the "release" command and watching for the return of the pinger trace it ought to be possible to confirm the operation of the release without using the TT301 receiver. The technique was not a great success. The pinger trace vanishes when the "window" command is acknowledged and returns either when the "release" command is acknowledged or when the "window" command times out after 90 seconds or so, and in practice it is not easy to tell whether the pinger has switched back on due to the release firing or due to the "window" command timing out. Because of winch limitations the deepest wire test was to 5000m.

## 3. Individual moorings

### 3.1.Mooring H

This mooring used RT 62 in a MORS pressure case with the lifting lug still in place. It was deployed in 4400m of water. Some slant ranges were obtained using the MAFF TT301. To observe whether or not commands were getting through from the IOSDL TT301, the "pinger on" command (20CD in this case) was transmitted. If the RT661 heard it, the pinger trace would jump by a random amount. This method was used on all subsequent tests to determine that the RT661 had heard a command. The Simrad echo-sounder was operated throughout all of the tests, and did not interfere with the reception of commands.

The pinger was switched on and the ship steamed away from the mooring position at 5kts until the pinger was no longer visible on the waterfall display. This was at a horizontal distance of 1.3 nautical miles, or a slant range of 4960m. To get a reply from the RT661, a command was transmitted by the TT301, and the "acknowledged" LED lit up when a reply was received. The maximum slant range at which the MAFF TT301 received a reply through the fish was 4800m. The pinger signal was at its strongest on the waterfall display with the ship overhead, becoming progressively weaker as the ship moved away, until it vanished below the ambient noise level. This was the case with all of the moorings. It was possible to get a command through to the release after the pinger was no longer visible on the waterfall display, making the pinger trace jump, so that when steaming back it re-appeared on the screen displaced from its former position.

### 3.2.Mooring G

This mooring used RT 58 in a MORS pressure case with the lifting lug and top ring removed. It was set down in 5900m of water. Trials were carried out using the same set-up as before, but the waterfall display had been modified so as not to load the signal line, and the gain of the waterfall card had been increased. This set-up remained the same for all subsequent trials.

The ship steamed away from the mooring position at 5kts, until the pinger was no longer visible. This occurred at a horizontal distance of 1.6nm, or 6500m slant range. When hove-to the pinger was visible at a distance of 1.9nm, or 6780m slant range. Commands from either TT301 would get through to the pinger at this range 80% of the time, but no replies were received by the MAFF TT301 at any range. Only one command was acknowledged by the MAFF TT301 through the PES fish (uncorrected range of 5879m). This was whilst over the top of the mooring, despite numerous attempts both there and further off.

3.3.Mooring F

This mooring used RT 55 with an IOSDL pressure case and ceramic ring transducer. It was set in 4260m of water.

The pinger was visible out to a distance of 1.3 nm (4830m slant range), but no ranges were obtained from the MAFF TT301 whilst under way at this range. Hove-to, only one command out of ten from the IOSDL TT301 was heard by the RT661 through the fish. The MAFF TT301 was tried with the dunking transducer, and one out of two commands were acknowledged (the TT301 giving a range of 5099m) before the battery pack unexpectedly died. Steaming back, the RT661 started hearing commands from the IOSDL TT301 at a distance of about 1nm (4600m slant range).

3.4.Mooring E

This mooring used RT 64 with an IOSDL pressure case and ceramic ring transducer. It was set in 3420m of water. Unlike all the other moorings, weather conditions were poor and deteriorating by the end of the mooring deployment, so tests were curtailed.

The pinger was visible out to a distance of 1nm (3850m slant range). The MAFF TT301 obtained slant ranges up to 3924m when steaming away, but would not switch off the pinger with the ship hove-to at a horizontal distance of 1nm, so the dunking transducer was used. It responded first time to the MAFF TT301 through the dunking transducer. The slant ranges for fixing the anchor position were obtained at a distance of about 0.5nm (3550m slant range) with the MAFF TT301 through the PES fish.

3.5.Mooring D

This mooring used RT 66 with an IOSDL pressure case and ceramic ring transducer. It was set in 2700m of water.

The ship steamed out to a distance of 2.3nm (slant range of 4070m) from the mooring. The large skew on the pinger repetition rate made it difficult to see the trace when moving away from it at any speed, but it was visible when hove-to at this range. Neither TT301 could command the RT661 through the fish, but the MAFF unit received five out of five replies at a slant range of 4900m using the dunking transducer. The ship then steamed to 3.5nm (slant range of 6730m) and the TT301 could still command the RT661 through the dunking transducer giving a range of 6642m.

3.6.Moorings C to A

These moorings used an RT661 with an IOSDL pressure case and ceramic ring transducer. They were set in water depths of 2380m, 1615m and 2915m. Due to the similarity with the previous moorings, as well as the consistency of the results achieved thus far, detailed ranging trials were not carried out. The results obtained while fixing the anchor positions confirmed the ranges obtained in the earlier trials.

## 4. Results

### 4.1 Summary

The ranging trials showed a remarkable similarity in performance between the pinger mode on the RT661 and the beacon mode on the CR200 in deep water when listening to them with a single PES element. The slant ranges and horizontal distances obtained are much what I would expect from a CR200 in these depths. The RT661, however, showed improved horizontal range when interrogated with the dunking transducer in shallower water. The acoustic output of the CR200 is quoted as 20 Watts with a pulse length of 2ms (Phillips 1981), which translates to 160dB referenced to 1μPa at 1m (Tucker & Gazey 1966). That of the RT661 is 192dB with a pulse length of 4ms (RT661 user's manual). The mushroom transducer has a conical beam of 120°, the beam pattern of the ceramic ring is a more complex "butterfly" pattern.

The RT661 can be interrogated reliably up to a slant range of 5000m using the TT301 through the single PES element. The pinger can be seen on the waterfall display to a much greater range. In shallower water (less than 3000m) the horizontal range is reduced because of the directivity of the PES transducer (diagram 1). In water deeper than 5000m, from the trial in 5900m, few if any replies are received by the TT301. In contrast, the RT661 can interpret commands correctly up to a slant range of 6600m, the limit of reception of the pinger, and possibly further.

The ceramic ring dunking transducer gives better ranges in shallower water, up to 6700m slant range in 2700m of water, and in deeper water, moorings E and F, a higher percentage of replies were received by the MAFF TT301 than through the PES transducer when the ship was at the extreme edge of pinger reception. The TT301 does not give a direct indication of signal strength such as can be deduced from a waterfall display of a pinger trace, apart from the percentage of commands that it fails to receive an acknowledgement for. There was little change in the number of these failures out to a slant range of 6000m+ in the quiet conditions experienced during most of the moorings.

The RT661s in the MORS ferallium cases did not give quite as strong a pinger signal as those in IOSDL cases, giving a lower signal strength on the waterfall display and little or no bottom echo. Despite this, similar maximum ranges were obtained for the pinger with both types (compare moorings H and F). There was no detectable improvement in acoustic performance when the lifting lug and top ring were removed from the ferallium case.

4.2 Tables of results:

Table 1:Mooring depth and slant ranges

| **Release** | **Slant ranges** | | | |
|---|---|---|---|---|
| depth | Pinger(PES) | TT301(PES) | RT661(PES) | TT301,dunker |
| 2700m(D) | 4890m | 3940m | >6730m | >6730m |
| 3240m(E) | 3850m** | 3550m | >3850m | >3850m |
| 4260m(F) | 4830m | 4600m | >4880m | >5099m |
| 4400m(H)++ | 4960m | 4800m | >4960m | - |
| 5900m(G)+ | 6780m | 5879m* | >6780m | - |

*One reply only.
**Poor weather, higher noise conditions.
+Ferallium case, lug & ring removed.
++Ferallium case, complete.

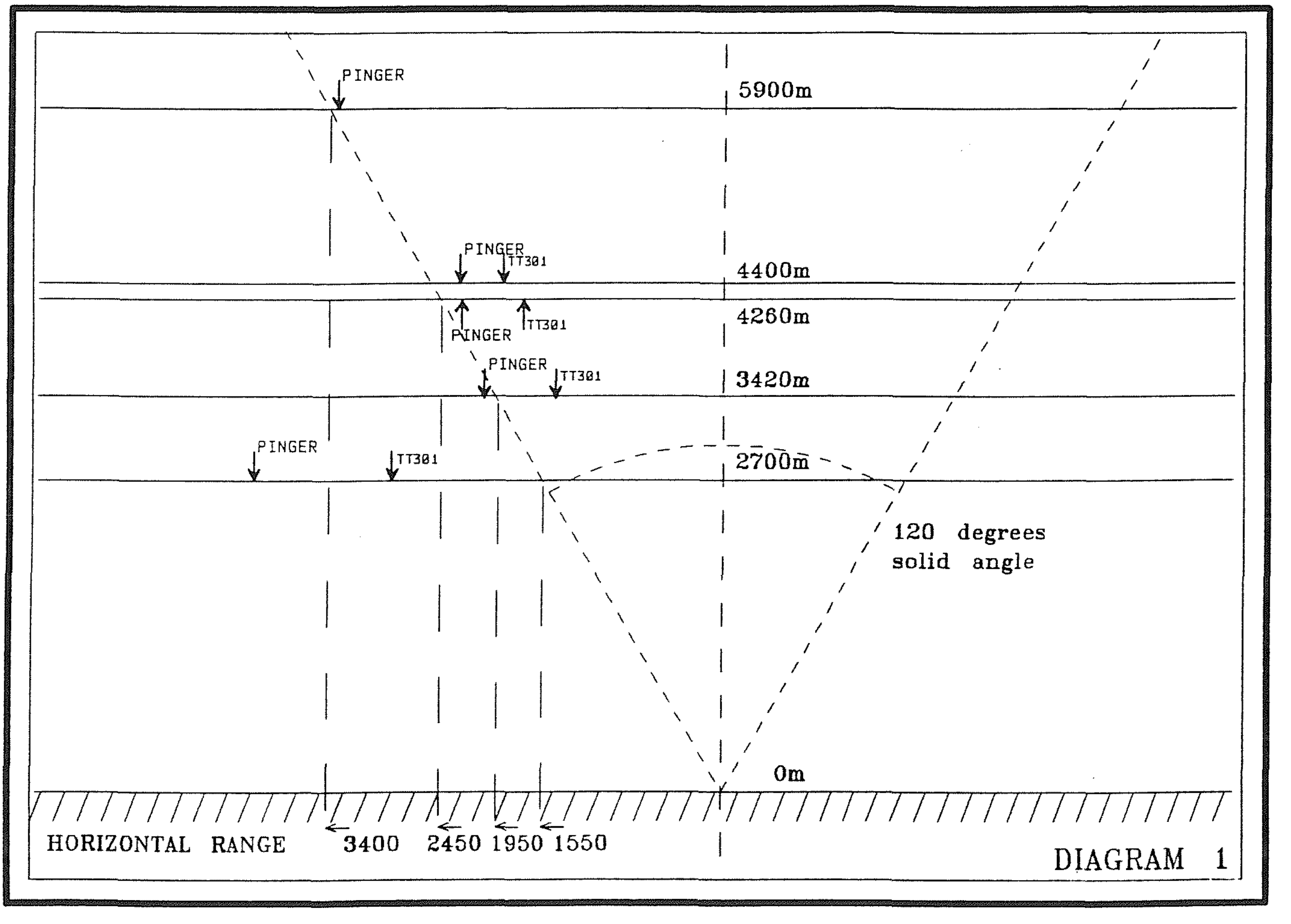
Table 1 shows, for each mooring, the depth of the mooring, the maximum slant ranges (corrected) at which the pinger could be received by the waterfall display through the PES, the maximum slant range at which the MAFF TT301 received replies from its commands through the PES, the greatest slant range at which the RT661 was successfully transmitted to through the PES and the greatest slant range at which the MAFF TT301 was used to transmit and receive commands with the ceramic ring transducer.

**Table 2: Summary of individual moorings results:**

| Mooring depth | overhead range(max) | TT301 range/pinger strength | | |
|---|---|---|---|---|
| 5900m(G) | 4123m | NIL/OK | steaming | 5kts, 0.7nm |
| | | NIL/WEAK | steaming | 5kts, 1.6nm |
| | | NIL/WEAK | steaming | 5kts, 1.9nm |
| | | NIL/OK | steaming | 5kts, 1.0nm |
| 4400m(H) | 4393m | 4595/OK | steaming | 5kts |
| | | 4773/WEAK | steaming | 5kts |
| | | NIL/NIL | steaming | 5kts,1.3nm |
| | | (?)4464/WEAK | hove-to, | 1.3nm |
| | | 4739/WEAK | hove-to, | 1.3nm |
| | | 4742/WEAK | hove-to, | 1.3nm |
| 4260m(F) | 4215m 4 at | 4215/OK | steaming | 5kts |
| | | NIL/WEAK | steaming | 5kts, 1.3nm |
| | | 1 RESPONSE OF 10/WEAK | hove-to, | 1.3nm, |
| | | | | IOSDL TT301,PES |
| | | 5099/WEAK | hove-to, | 1.3nm, |
| | | | | MAFF TT301,dunker |
| 3240m(E) | 2394m | 4215/OK | steaming | 5kts |
| | | (several successful ranges up to:) | | |
| | | 3924/OK | steaming | 5kts, 1nm |
| 2700m(D) | 2742m | 2880/OK | steaming | 5kts |
| | | 3182/WEAK | steaming | 5kts |
| | | (several successful ranges up to:) | | |
| | | 3940/WEAK | steaming | 5kts |
| | | NIL/NIL | steaming | 5kts, 2.3nm |
| | | NIL/WEAK | hove-to, | 2.3nm, PES |
| | | 4892,4910,4927,4936,4942/- | hove-to, | 2.3nm, |
| | | | dunker, | 100% replies |
| | | 6642/- | hove-to, | 3.5nm |
| | | | dunker, | 100% replies |
| | | 4830,4834/- | hove-to. | |
| | | | dunker, | 100% replies |

Table 2 **shows** the mooring depth, the maximum range measured by the TT301 during deployment, and the signals received during ranging trials: the range(s) obtained by transmitting a command is shown with an estimation of pinger strength, together with any relevant comments. Where the dunking transducer was used, the pinger strength was not observable.

Diagram 1: Maximum range at which the pinger was heard and at which the TT301 received acknowledgement of commands superimposed on the nominal beam pattern of a PES transducer.



## 5. Conclusions and Comments

### 5.1.General Set-up

For deploying and recovering RT661 acoustic releases from a horizontal range of 1 nautical mile, a TT301 together with an IOSDL waterfall display running through the single element of the IOSDL PES fish is adequate in depths from 1500m to 6000m. As can be seen in diagram 1, the main limitation on range is the beam pattern of the PES transducer. If greater range is required, particularly in water less than 2000m, a ceramic ring transducer in a towed fish (such as the IOSDL "Dolphin") would give better results, as shown on mooring D. This is because of the better matching of the TT301 receiver to a ceramic ring, as well as the directivity of the PES transducer, which is a handicap in shallow water. It would also provide a compact, self-contained system when no PES fish is available. For water depths greater than 5000m, although no ranging was carried out using the ceramic ring on mooring G, the ceramic ring transducer may well have given better results. This is inferred from the greater ranges obtained when the dunking transducer was used, particularly on mooring F, and the fact that the ceramic ring on the RT661 worked well at slant ranges of up to 6900m. Although virtually no replies from the RT661 were received by the TT301 through the PES transducer at 5900m water depth, the RT661 had no trouble receiving commands from the TT301 and the waterfall display showed that the pinger signal from the RT661 could be heard at the ship at up to 6900m slant range. The only time the RT661 had difficulty hearing either TT301 was on mooring F, when the problems with the battery packs were first encountered. If the greater directivity of the PES element is required, a PES transducer in a Dolphin could be used, but there is no direct evidence from these trials to suggest that this would be any better than a ceramic ring at depths up to 6000m and slant ranges up to 6900m. It was not possible in this case to try all nine elements of the PES fish in parallel, but the indirect evidence suggests that the ceramic ring produces enough power to work in this depth and at greater slant ranges than a single PES element.

Other work has suggested that the RT661 and the TT301 cannot commmunicate below 3000m (Mueller 1993). This may have been for a number of reasons: for lack of transmitted power, (they had no way of monitoring the RT661 independently of the TT301, as we did with the pinger and the waterfall display,) in which case the improved directivity of the PES transducer could be advantageous; or it may have been due to receiver variability (see 5.3, para 2). It was not the case during these trials which showed that the ceramic ring dunking transducer will work in water depths of at least 4200m and at slant ranges of greater than 6900m.

5.2.Ranging trials

The horizontal range of the RT661 is somewhat better in shallower than in deeper water, although the maximum slant ranges obtained with the dunking transducer remain similar, at about 6700m. This supports the impression that the range of the RT661 is limited by the power of its transmission only, not by the supposed limitations of its transducer, and that this is in excess of 6700m in low noise conditions. The transducer does not appear to have any measurable nulls in its beam pattern, and in deep water gives the appearance of being omnidirectional. On a waterfall display looking through the single PES element the signal strength of the pinger is comparable to an IOSDL CR200 with a "mushroom" transducer in water depths up to 5900m, and the signal fades gradually as the ship steams away from it.

It was not possible to test the waterfall display through the dunking transducer (ceramic ring), although trials on *Alkor* with Kiel University in shallow water in February 1993 did not indicate any problems with this configuration.

5.3.Performance of the TT301

The performance of the TT301 receiver deteriorates with the weather (or any other increase in ship noise), although adequate results were achieved on mooring "E" in a force 7-8 using the MAFF TT301 through the PES fish in 3400m of water.

From these trials and those on the *Alkor* it would appear that there can be considerable variation in receiver sensitivity. The waterfall display gives a better idea of what is going on than the digital display on the TT301. It is especially useful when watching for mooring lift-off or touch-down. A missed reply on the TT301 rarely means that the command has not been heard by the RT661, especially with the ship hove-to over the mooring site, whereas in heavy weather the number of false replies can make interpretation of the TT301 ranges tricky.

There were problems with both TT301's battery packs. If the battery pack gets low, the TT301 will not transmit the correct code. Most commonly it replaces the code display with "CCCC" as it gives a dying squawk. This can occur even when the unit is plugged into the mains on "standby". Running the unit permanently on trickle charge does not appear to provide much of a net charging effect if the unit is left switched on: prior to mooring "F" the MAFF TT301 had been left switched on and permanently plugged-in on stand-by, yet the battery was virtually flat. Both packs were discharged and charged up again, but an external 24V DC supply would be highly desirable.

5.4.Use of the RT661

The "release" command is particularly difficult to interpret when relying on a waterfall display on a wire-test (para 2.3). The time for which the pinger is switched off awaiting the "release" command after receiving the "window" command only really allows two attempts to get a command through. If the first one fails it is not always clear that the pinger has started again because the command has been received, or the RT661 has timed out of its window. If a longer window were allowed, say five minutes, this would allow much less ambiguity.

The RT661s in IOSDL aluminium pressure cases all gave a good signal and, in contrast to the ferallium cases gave an excellent bottom echo. This was expected, since the IOSDL tube with a face-seal to the transducer mounting should transmit more acoustic energy than the ferallium case with a piston seal in the same place. The IOSDL case is also noticeably lighter making a double-release unit almost manageable.

## 6. Recommendations

The recommended deck system is two TT301 deck units with an IOSDL waterfall display (including back-up computer and software). If there is no PES fish with a single element available a PES or ceramic ring transducer in a Dolphin should be considered. A MORS ceramic ring dunking transducer comes as standard with each TT301.

The dunking transducer as supplied by MORS is vulnerable and some sort of protective cage should be devised for it. The cable and transducer should also be stored on a reel.

The strongest pinger signal was obtained with the RT661 mounted in an IOSDL aluminium pressure case. In particular, the strong bottom echo helps enormously in determining time of lift-off, etc. If pyros are the preferred method of release operation, then this is the recommended option; the aluminium case with its titanium bar and release mechanism is lighter and easier to handle than the ferallium case, and there are no questions of possible crevice corrosion as there are with ferallium or any other stainless steel. Longer tubes (30-inch) that can contain more batteries are available for longer deployments, or for similar length deployments using alkaline cells. It also allows the re-use of titanium stocks as CR200s are taken out of service. It is important when ordering these that the long (older design) titanium bars are specified, and that if 30-inch tubes are to be used then longer bars will need to be made up.

Some of the releases, RT 62, 65 and 55 have a noticeably skewed trace, i.e. their internal clock rate is much slower than it should be by about 0.1ms to 0.5ms. This makes it very difficult to see the trace when steaming away, and difficult to judge things like descent rate, time on bottom, etc. All new RT661s should be checked before acceptance, either on a counter timer to the nearest 0.1ms or on a waterfall display.

The TT301 as purchased by IOSDL runs off a battery pack that can be charged from the mains. If this is not properly charged up, or if it becomes faulty the TT301 cannot transmit properly. For greater reliability, an independent 24VDC 5-amp power supply should be used.

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