I.O.S.

PERFORMANCE OF THE LOW PRESSURE DIFFERENTIAL AND ABSOLUTE DIGIQUARTZ PRESSURE TRANSDUCERS

BY

A.D. BANASZEK

REPORT NO. 215

1985

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF
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When citing this document in a bibliography the reference should be given as follows:-

BANASZEK, A.D. 1985 Performance of the low pressure differential and absolute digiquartz pressure transducers. *Institute of Oceanographic Sciences, Report*, No. 215, 34pp.

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ABSTRACT

The Digiquartz pressure transducer (PAROS 1976) is a highly accurate sensor which has found use in the measurement of sea level elevations. By investigating the sensor characteristics, long term stability and the response of the transducer in the sub-millibar region, the overall performance of the low pressure differential and absolute sensors is assessed.

1. INTRODUCTION

The 2 Bar differential Digiquartz and the 0-27 Bar absolute version have been used by the I.O.S for shore based and Continental Shelf sea-level elevation measurements. The output from these transducers is in the form of a frequency which varies between 40kHz and 36kHz over the full pressure range.

Both the differential and absolute transducers are incorporated in the Aanderaa Series 500 and 600 Water Level Recorders. With the WLR 500 series the average transducer output period is measured by counting a chosen number of periods and gating this with an appropriate time base. Since the frequency output change from the transducer only amounts to 10%, the time taken to accumulate a given number of period counts is roughly constant (56 seconds) and is termed the "integration time".

The 600 series of recorders however, use a true integration time of 40 seconds. In this case, as the output from the transducer decreases with increasing pressure the output pulses are made to count down a pre-set counter. The left over in the counter, when the integration time has elapsed, gives the pressure count reading. The counter is pre-set to 1640000 and will count all the way down to zero when the output frequency is 41kHz. This series of instruments has a temperature sensor fitted enabling temperature corrections to be made to the pressure transducer data as well as giving the environmental temperature signal. The earlier WLR 500 instruments do not have this temperature sensor fitted.

At the I.O.S, the absolute transducers, along with a highly stable low power temperature sensor, are incorporated into instruments which contain many of the mechanical features of the Aanderaa instruments, but modified electronics provide integration times of 900 seconds. Differential transducers are used in shore based bubbler systems for long term sea level measurements.

This report discusses the calibration techniques needed to derive the secondary sensitivities necessary for the detailed interpretation of the data.

To make an assessment of the long term stability of these transducers, emphasis is placed on the many years of available calibration data. In addition, a series of experiments were carried out in the laboratory to measure stability and in the case of the differential transducers, to determine common mode line pressure effects.

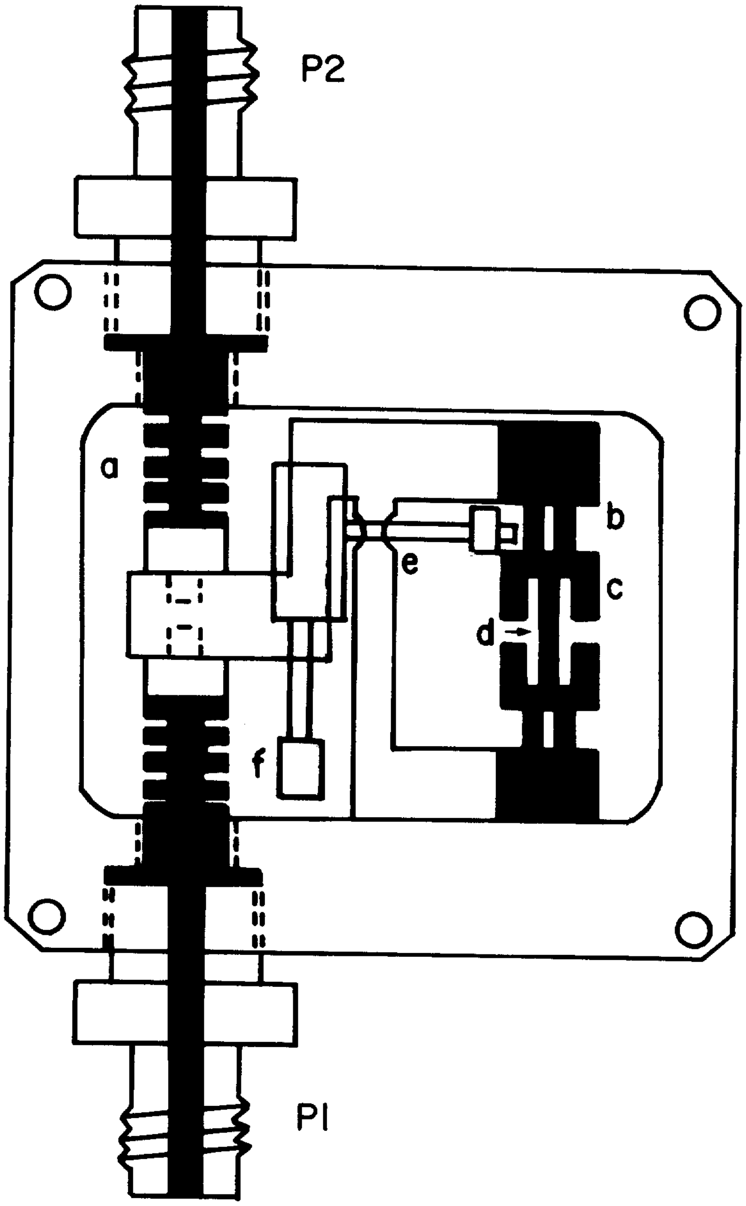
The factors which contribute to the overall stability are discussed along with an assessment as to how effective the instruments are for making sea level elevation measurements.

2. SENSOR OPERATION

In the Digiquartz transducer, pressure is applied to the port P1 (Figure 1) and is converted into an axial force by the bellows. This force causes the suspension arm to pivot about a flexible pivot point, resulting in a compressive force on the quartz crystal resonator beam. An electronic oscillator circuit drives the quartz beam at its natural resonant frequency. At zero applied pressure the output frequency is of the order of 40kHz whereas at full scale pressure it decreases to 36kHz.

The pressure transducer operates inside a stainless steel case held at a very high vacuum. This is necessary for the operation of both the differential and absolute sensors to minimise damping effects on the quartz resonator beam.

In order to make the transducer as insensitive as possible to vibration and orientation, balance weights are attached to make the centre of mass of the whole transduction system reside at the centre of the flexible pivot point. The degree to which the sensor is insensitive to orientation is discussed later.



a. Bellows

b. Isolator spring

c. Quartz isolator mass

d. Vibrating quartz beam with electrodes deposited on the surface

e. Flexible pivot point

f. Balance weights

Note: Absolute transducers with serial numbers up to 1629 have internally pressurised bellows. Those which follow have externally pressurised bellows as depicted opposite.

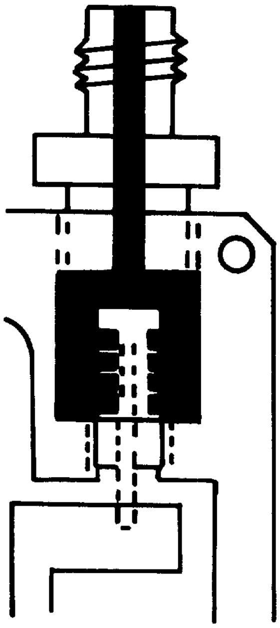


Fig 1. Schematic layout of a differential Digiquartz pressure transducer incorporating internally pressurised bellows.

3. SENSOR CALIBRATION

When differential or absolute transducers are mounted inside a 12 cm diameter, 30 cm long aluminium alloy pressure case the response of the sensor to environmental temperature changes is highly damped. These instruments are placed in a temperature controlled bath and allowed to stabilise for several hours. A calibration over the full pressure range is carried out using an air operated dead weight tester and the process repeated over the full temperature range of say 0-35°C in 5 degree C steps. Normally a pressure calibration run will take at least one hour, whilst several days are needed to do a complete calibration.

From the processed calibration data set the temperature and pressure sensitivities are derived along with the hysteresis (BANASZEK 1985).

Paroscientific, the manufacturers of these transducers, recommend fitting the experimental data to a 3rd order polynomial of the form

$$P = A(1-F/FO) + B(1-F/FO)^2 \qquad (1)$$

where P = applied pressure in bars

FO = transducer output frequency at zero applied pressure

F = " " " " pressure P

A and B are the required calibration constants in dimensional units of pressure.

With Aanderaa Water Level Recorders the FO and F are replaced by the total zero pressure count KO and total pressure count K respectively.

Rearranging equation (1) gives

$$P/(1-F/FO) = A+B(1-F/FO)$$

so that P is forced to be zero at F=FO. The output frequency and the pressure may be substituted into the above equation and the equation solved for A and B by the method of least squares.

In the majority of cases an equation of form (1) will fit the data from a

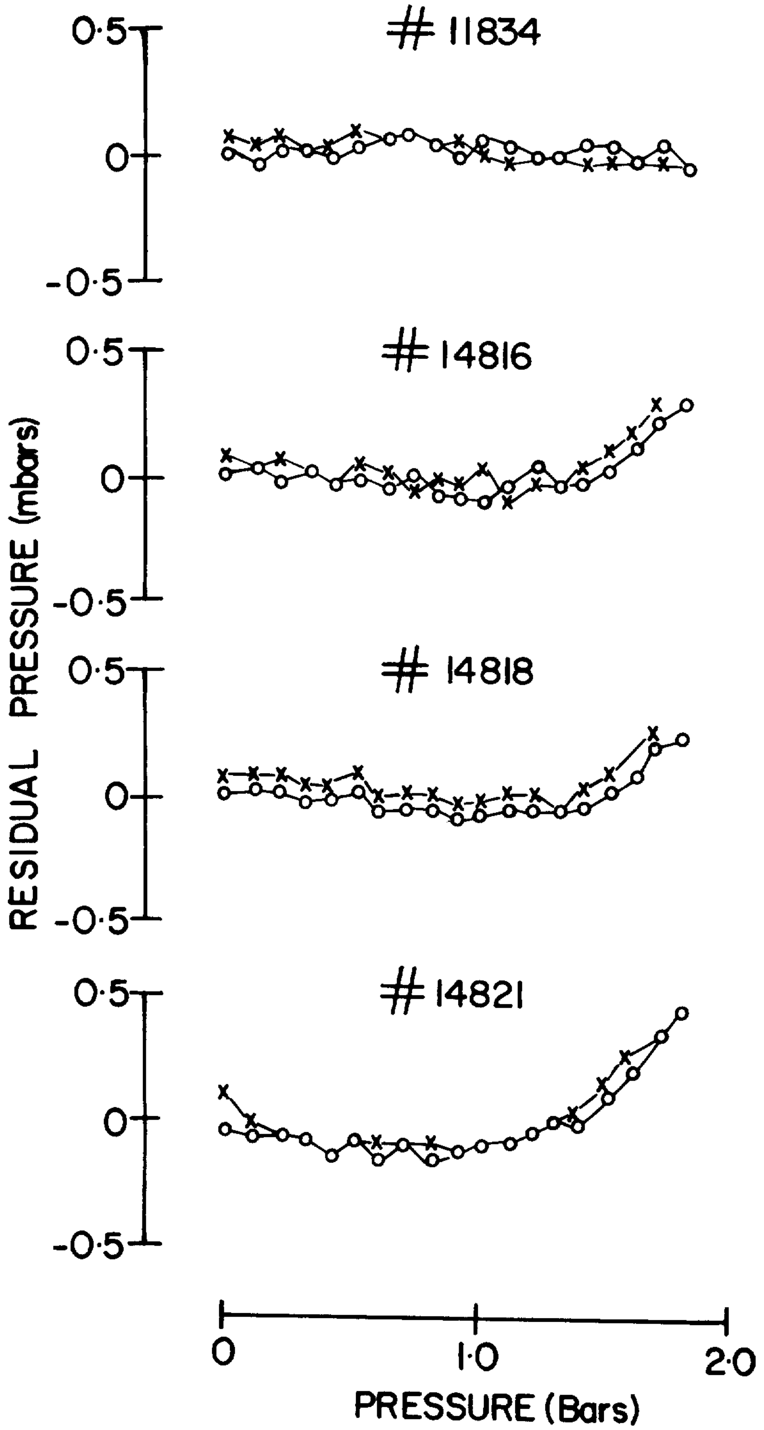


Fig 2. Hysteresis and calibration uncertainty associated with the 2 Bar differential Digiquartz transducer after the calibration data has been fitted to an equation of the form $P = Ax + Bx^2$.

differential transducer very well. However, Figure 2 shows the residual error plots for four transducers, #11834,#14816,#14818 and #14821 where only #11834 is well fitted. The other three are best fitted by including an extra term $C(1-F/FO)^3$ into equation 1. This should be considered if the transducer is to be used over its full pressure range. From the residual error plots the non-repeatability and hysteresis associated with each transducer, can be displayed. Usually the hysteresis is very low indeed, typically 0.1mb for differentials and 0.5mb for 27 Bar absolutes.

At the I.O.S, low pressure absolute transducer calibration data is fitted to a fourth order polynomial equation of the form

$$P = a + bX + cX^2 + dX^3 \tag{2}$$

with X normalised to lie between +1 and -1, so that

$$X = (2F-C-D)/(C-D)$$

where F = sensor output frequency at applied pressure P.

C = lower limit for sensor output frequency

D = upper " " " " "

again, a,b,c and d are the calibration coefficients for the sensor at a specified temperature.

3.1 TEMPERATURE SENSITIVITY

Changes in transducer output, due to the effect of temperature, at various pressures are shown in Figure 3. The actual temperature sensitivity in millibars/degree C is obtained by calculating the slope of the curves. For most differential transducers the temperature sensitivity is of the order of ± 0.05 mb/degree C between 0° and 35°C. A similar value is found with absolute transducers but over a smaller range of temperature.

The temperature sensitivity of differential transducers is pressure dependent

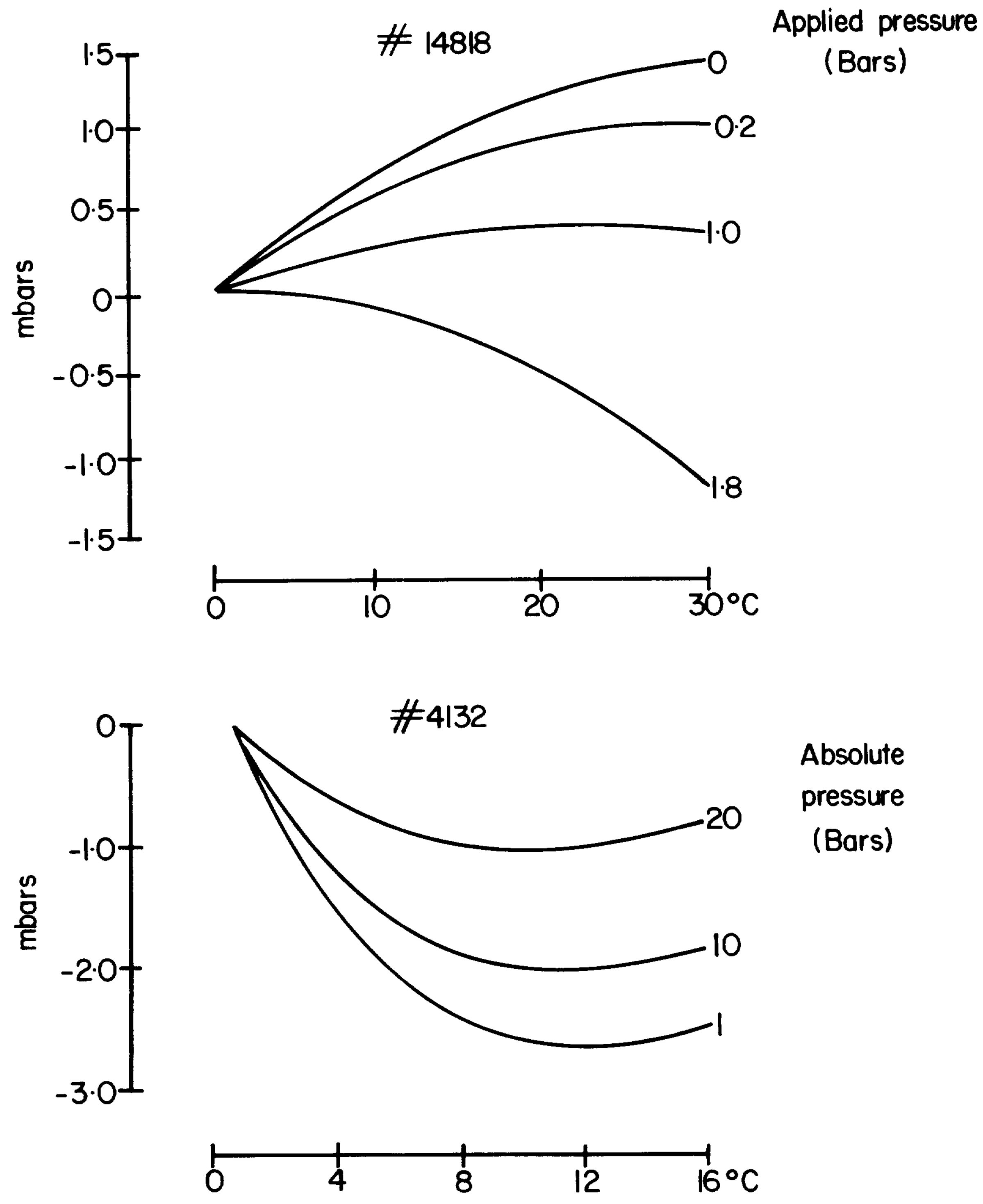


Fig 3. Effect of temperature, at fixed pressures, on the output of a 2 Bar differential Digiquartz (#14818) and a 27 Bar absolute Digiquartz (#4132). In both cases the 0°C values have been chosen as a reference. The temperature coefficient in mbs°C^{-1} is given by the slope of these curves.

because of the mechanics of the bellows arrangement and the fact that the bellows are internally pressurised. The change to externally pressurised bellows in the absolute transducers has helped to reduce this dependence.

3.2 PRESSURE SENSITIVITY

To calculate the pressure applied to a differential transducer requires a knowledge of the zero pressure frequency (FO) and the pressure sensitivity, derived from equation (1) as follows:

$$P = Ax + Bx^2$$

where $X = (1-F/FO)$

or $Bx^2 + Ax - P = 0$

and $x = (-A + \mathrm{sqrt}(A^2 + 4BP)/2B$

Pressure sensitivity $dF/dP = (dx/dP)(dF/dx) = FO/(\mathrm{sqrt}(A^2 + 4BP)$ (3)

defined at constant temperature and having units of Hz/mb.

For the Aanderaa Water Level Recorders, a similar approach gives

$$dK/dP = (K^2/KO)/(\mathrm{sqrt}(A^2 + 4BP)) \qquad (4)$$

with K defined as the total pressure count.

The pressure sensitivities of several WLR instruments, differential and absolute transducers are given in Figure 4. In all cases, the sensitivity increases with increasing pressure, due to the fact that the effective area of the bellows decreases with pressure. It is interesting to note that the pressure sensitivity of the absolute transducers is an almost linear function of pressure which is not the case for the differentials. Again, this is due to the design of the externally pressurised bellows in the absolute trandsducers.

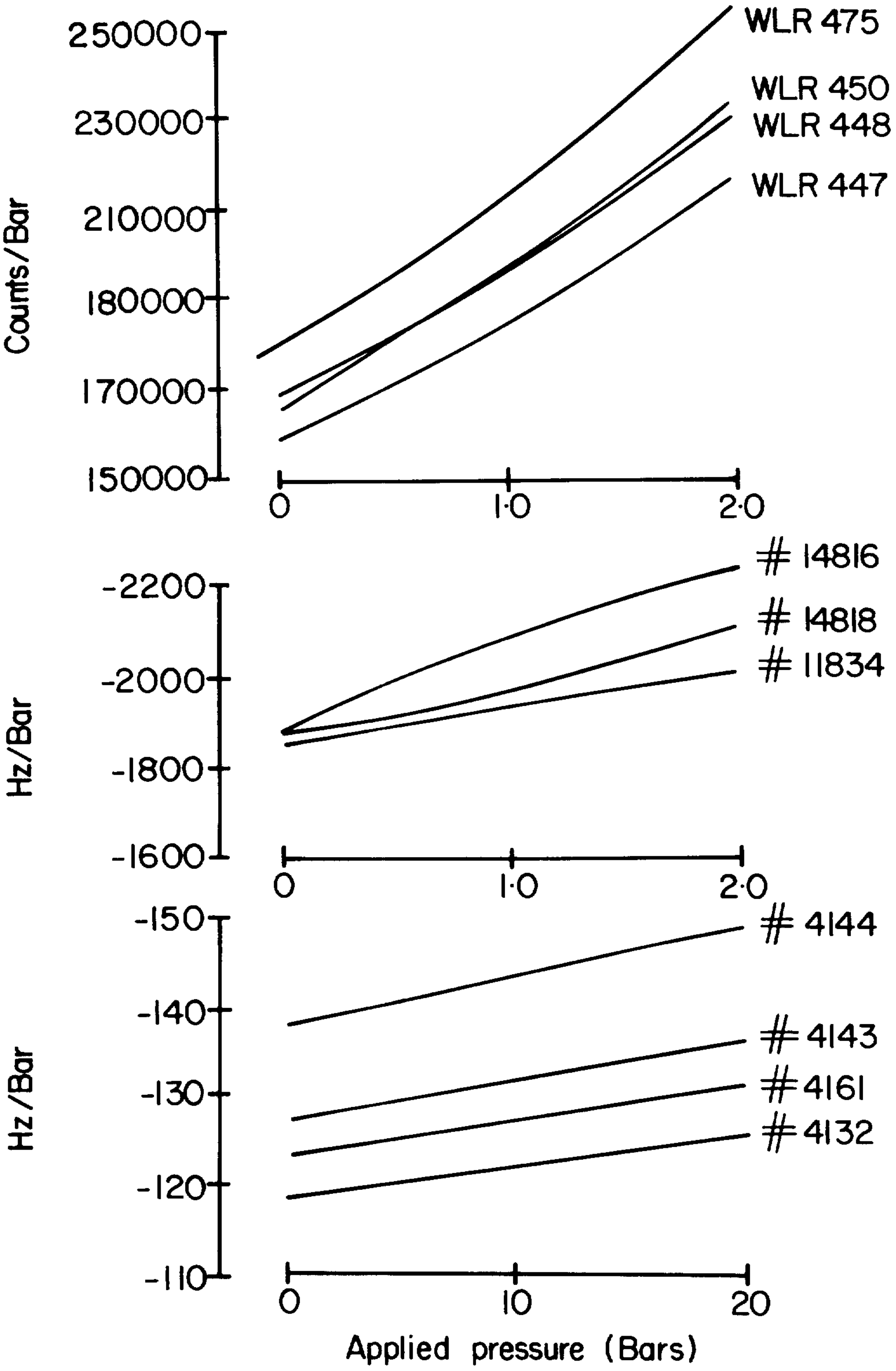


Fig 4. Pressure sensitivities as a function of pressure for 2 Bar differential Water Level Recorders, 2 Bar differential transducers and 27 Bar absolute Digiquartz transducers.

4. CORRECTING PRESSURE DATA FOR THE EFFECTS OF TEMPERATURE

Although most of the transducers are relatively insensitive to the effects of temperature it is still desirable to remove the effect if high accuracy is called for.

From the calibration equations (1) obtained at different temperatures, the calibration constants A and B are related to the temperature in the following way

$$A(T) = k_1 + k_2T + k_3T \tag{5}$$

$$B(T) = k_4 + k_5T + k_6T \tag{6}$$

$$F_0(T) = k_7 + k_8T + k_9T \tag{7}$$

where kn are the new calibration constants and T the temperature.

$$P(T) = A(T)x + B(T)x^2 \tag{8}$$

For a given frequency and temperature these equations (#14818) can be used to calculate pressure. For a typical 2 Bar differential transducer the differences between the calculated and applied pressures are listed in Table 1. This gives a measure of how effective the equation is for removing the temperature signal.

TABLE 1.

TEMPERATURE CHANGE	CALCULATED PRESSURE - DEAD WEIGHT TESTER PRESSURE (MILLIBARS)				
DEGREES C	0 Bar	0.5 Bar	1.0 Bar	1.5 Bar	2.0 Bar
0.41	-0.014	+0.021	-0.011	0	-0.023
3.81	+0.005	+0.084	+0.015	+0.008	+0.003
9.14	+0.017	+0.059	-0.008	-0.032	-0.072
15.12	+0.024	+0.054	+0.030	-0.027	-0.017
20.14	-0.029	+0.049	+0.013	-0.006	-0.043
25.30	-0.025	-0.003	-0.022	-0.012	-0.057
30.80	-0.003	-0.022	+0.011	+0.011	+0.039

5. FACTORS AFFECTING THE DATUM STABILITY OF 2 BAR DIFFERENTIAL and 0-27 BAR ABSOLUTE DIGIQUARTZ TRANSDUCERS

All 20 of the Aanderaa Water Level Recorders at the I.O.S. use the shock mounted differential Digiquartz tranducer and these are mainly used as shore based pressure recorders. Repeated calibrations over the years reveal that changes in output and sensitivity have occurred. Results typical of these instruments are shown in Table 2, whilst Figure 5 gives the overall change in output and sensitivity with time.

TABLE 2.

STABILITY OF 2 Bar DIFFERENTIAL WATER LEVEL RECORDERS

INSTRUMENT SER.NO	CALIBRATION DATES	LENGTH OF DEPLOYMENT (MONTHS)	SHIFT IN OUTPUT BETWEEN CALIBRATIONS IN MBS.		
			0 Bar	1.0 Bar	2.0 Bar
WLR 447	5/79,6/80	2	-0.46	-0.50	-0.29
	9/82	11	+0.62	+0.82	+0.71
	7/83	9	+0.16	+0.32	+0.46
WLR 448	5/79,10/80	14	+0.25	-0.91	-0.49
	3/82	14	-0.74	+0.91	-0.28
	9/83	9	+0.72	+0.44	+0.04
WLR 450	5/79,5/84	25	-0.05	-0.09	-0.46
WLR 475	6/80,5/84	20	+1.66	+2.76	+3.00

Figure 6 depicts the change in output representative of two out of the three transducers (#11834,#14816 and #14818) obtained and calibrated in 1982, and calibrated again in 1984. Unlike the WLR instruments, these transducers were unused during this period. #11834 showed a negligible change in sensitivity over this time interval but did show a shift in the zero applied pressure output of the same magnitude as the other two transducers.

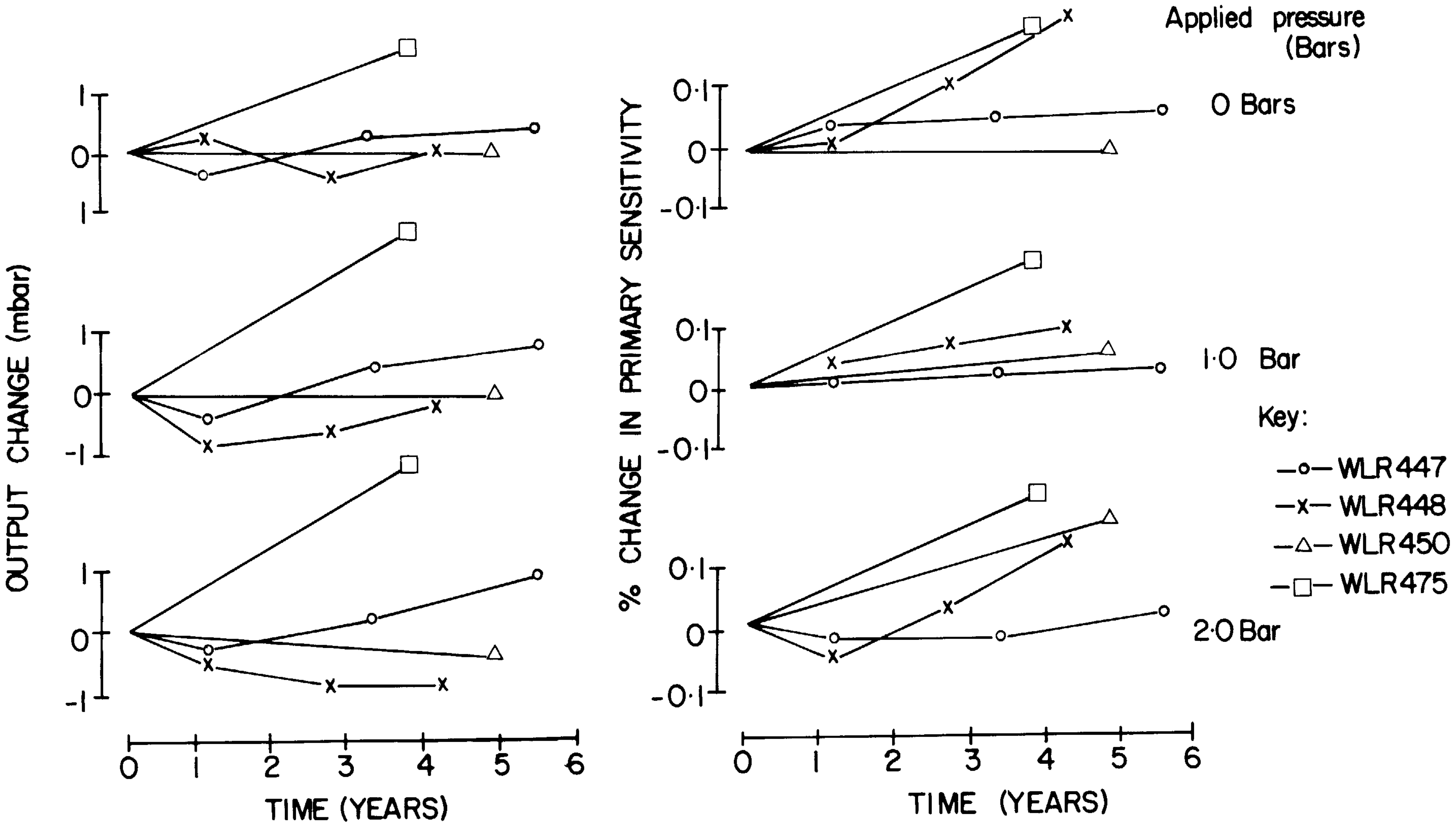


Fig 5. Changes in the output and primary sensitivity of Water Level Recorders incorporating 2 Bar differential Digiquartz transducers.

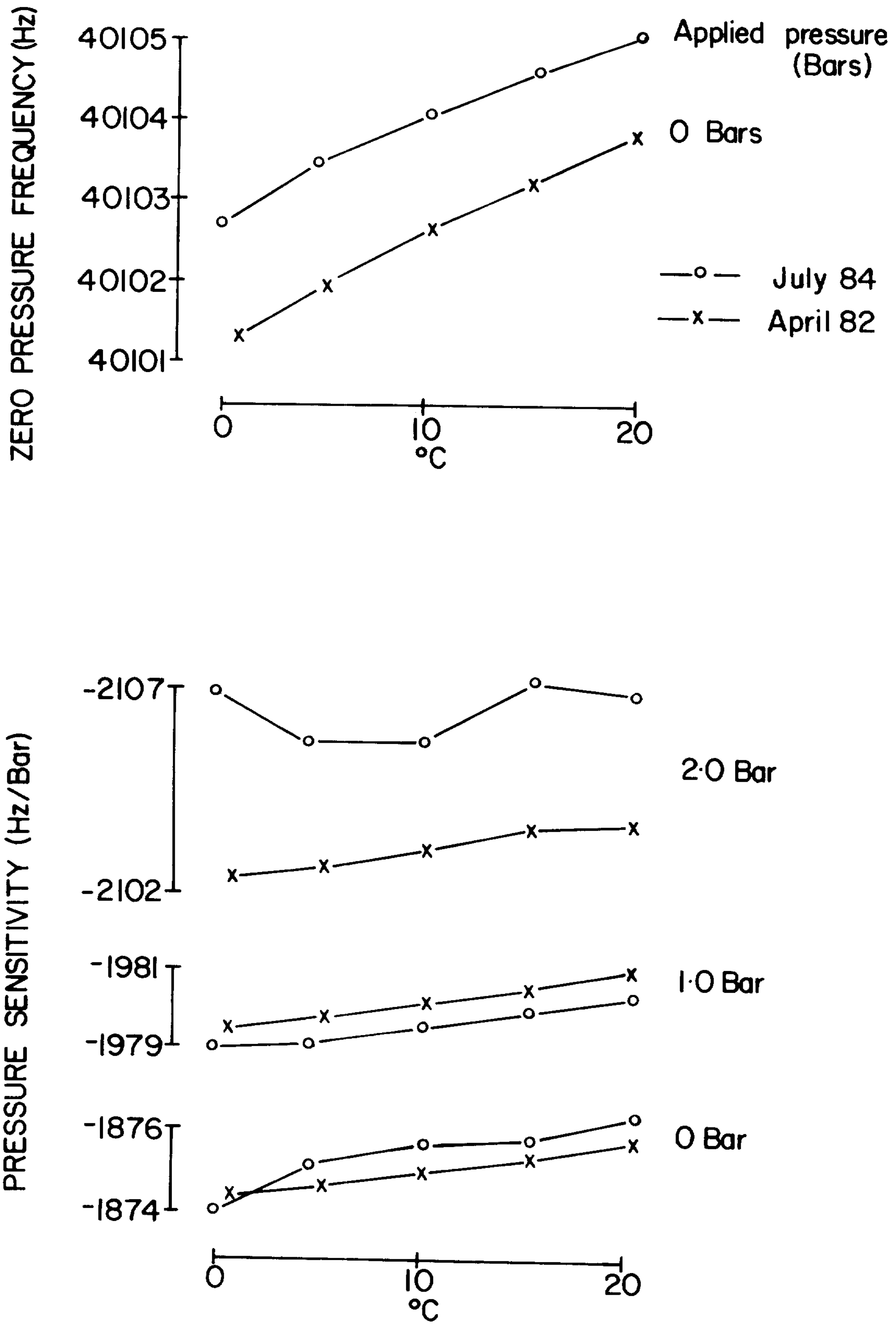


Fig 6. Typical variations in zero pressure frequency and primary sensitivity with respect to temperature and time for a 2 Bar differential Digiquartz (#14818).

Table 3 gives the observed changes in output between calibrations of several absolute transducers deployed on the Continental Shelf in depths up to 200 metres.

TABLE 3.

STABILITY OF 0-27 Bar ABSOLUTES.

INSTRUMENT SER.NO	CALIBRATION DATES	SHIFT IN OUTPUT BETWEEN CALIBRATIONS IN MBS.		
		1.0 Bar	100 Bar	200 Bar
S/N 4132	3/79,4/80	+10.4	+9.3	+7.1
	2/81	-3.4	-4.8	-5.7
S/N 4143	3/79,8/80	+6.2	+9.4	+9.1
	2/81	+4.7	+2.1	+0.6
S/N 4161	3/79,2/81	+25.0	+27.1	+26.3
WLR5-444	3/82,8/84	+5.1	+4.9	+3.5
WLR5-445	3/82,8/84	+10.4	+8.4	+6.2
TG2A-64	11/78,12/79	+12.3	+22.0	+30.7
WLR5-500	7/80,4/81	-	+5.4	-
	7/81	+2.4(6.0 Bar)	-	-
	3/84	-	-	-45.0*

Note: Transducers S/N 4132,4143,4161 have been used in Bottom Mounted Current Meter/Tide Gauge (HARRISON 1981) instruments, all of which suffered damage from trawlers.

WLR5-445 was dropped from an oil drilling barge to the sea surface.

*WLR5-500 Instrument rig washed ashore in Norway during CONSLEX exercise 82/83.

The data from both types of sensor show that changes in output and sensitivity do occur, in some cases irrespective of whether or not the transducer is deployed.

There are several possible mechanisms which could give rise to these changes, namely

(1) Degradation of the internal vacuum.

(2) Ageing of the quartz crystal resonator.

(3) Changes in crystal clock frequency (applicable to WLR) instruments)

(4) Changes in the dead weight tester pressure standard.

(5) Reversible and irreversible drift processes.

(6) Common mode line pressure effects (differential transducers)

(7) Shock.

(8) Orientation of the transducer.

5.1 Degradation of the internal vacuum.

If the internal vacuum of the transducer is not maintained then the pressure build up causes mass loading on the quartz crystal resonator which will lower the resonant frequency, indicating a higher applied pressure. However, an increase in internal pressure will also decrease the effective pressure across the bellows, indicating a lower applied pressure (BUSSE 1978). During the manufacturing process the transducers will have been carefully leak tested but in the long term, degradation of the epoxy resins used in the seals, may cause problems. The transducers examined here do not seem to suffer from this problem.

5.2 Ageing of the quartz crystal resonator.

This tends to lead to a higher indicated pressure, the process being dependent upon how long the crystal is allowed to oscillate. The evidence available (BUSSE 1978) suggests that following manufacture, the drift in the first month will be 0.038% of full scale pressure, 0.011% in the second month, and 0.006% in the following seven months. For a differential transducer the expected change in output would be +1 mb in the first few months of operation. This cannot account for the drifts observed in Table 2 but could account for drifts up to +10 mbs in the absolute transducers, since these were used shortly after purchase for short term deployments of a few months duration.

Pre-ageing of the new transducer by leaving it powered up for a few months should produce an improvement.

5.3 Changes in crystal clock frequency.

The Aanderaa WLR instruments have an inbuilt crystal clock and the output from this can be expected to be temperature dependent. The effect will be repeatable and will contribute to the overall temperature sensitivity derived from the calibration data. The crystals do suffer ageing but to account for a change of 0.5 mb per year the crystal would have to age by 25 ppm/year. The literature on this subject suggests that ageing rates of 0.5 to 3.0 ppm/year are more realistic. This is not likely to be a problem with the basic transducers since these are calibrated using precision frequency counters, whose accuracy can be easily verified.

5.4 Changes in the dead weight tester pressure standard.

If a dead weight tester is used frequently over a long period of time then small changes in the effective cross sectional area of the piston assembly take place, leading to a drop in pressure. Also, if cast iron loading weights are used, then slight mass increases can result from oxidation. In general these two processes tend to counteract one another. With the D.W.T. used to calibrate our instruments, recertification by the manufacturers has not revealed any detectable change in the overall accuracy over a five year period.

5.5 Reversible & Irreversible Drift Processes associated with the 2 Bar differential and the 0-27 Bar absolute transducers.

To confirm whether the changes observed in Table 2 could be a result of sensor instability a series of experiments were performed under laboratory conditions.

Three 2 Bar differential transducers, #9744,#18452 and #17673 were connected up to a D.W.T, along with a dial gauge and shut off valve, and alternately pressurised to 1 Bar and depressurised to atmospheric pressure. The same experiment was repeated at 2 bar but for a shorter length of time. Figure 7 shows the change in the temperature corrected pressure sensor output. The data used has been corrected for the effects of temperature on the D.W.T. piston assembly. Several interesting observations can be made from this data.

The drifts observed when the transducers are pressurised and depressurised are exponential in nature, the output in all cases, tending toward higher frequency (i.e. lower pressure). An exponential of the form A(1-exp(-Bt)) gives a good fit to the data.

where A = drift amplitude

B = 1/time constant (time constant = 40 hours)

t = time in hours

The first depressurisation to atmospheric pressure results in a DC shift in frequency, sometimes -ve in the case of #18452 and #17673 and +ve for #9744. Subsequent depressurisations reveal further DC shifts, often of decreased magnitude.

Repressurisation to 1 Bar results in a DC shift in output followed by an exponential drift. In this case the output appears to settle down to the static value attained during the first pressurisation. Subsequent pressurisations confirm this pattern of behaviour.

Prior to the third pressurisation to 1 Bar i.e. between day 49 and 53, (not shown in Figure 7) all three transducers were calibrated from 0-2 Bar in 0.1 bar steps, and over the temperature range 0-35°C in 5 degree steps. The drift in the sensor outputs still showed the same initial exponential drift pattern, with the output settling down to the static value attained in the first two pressurisations. A later experiment, in which transducer #17673 was cycled from

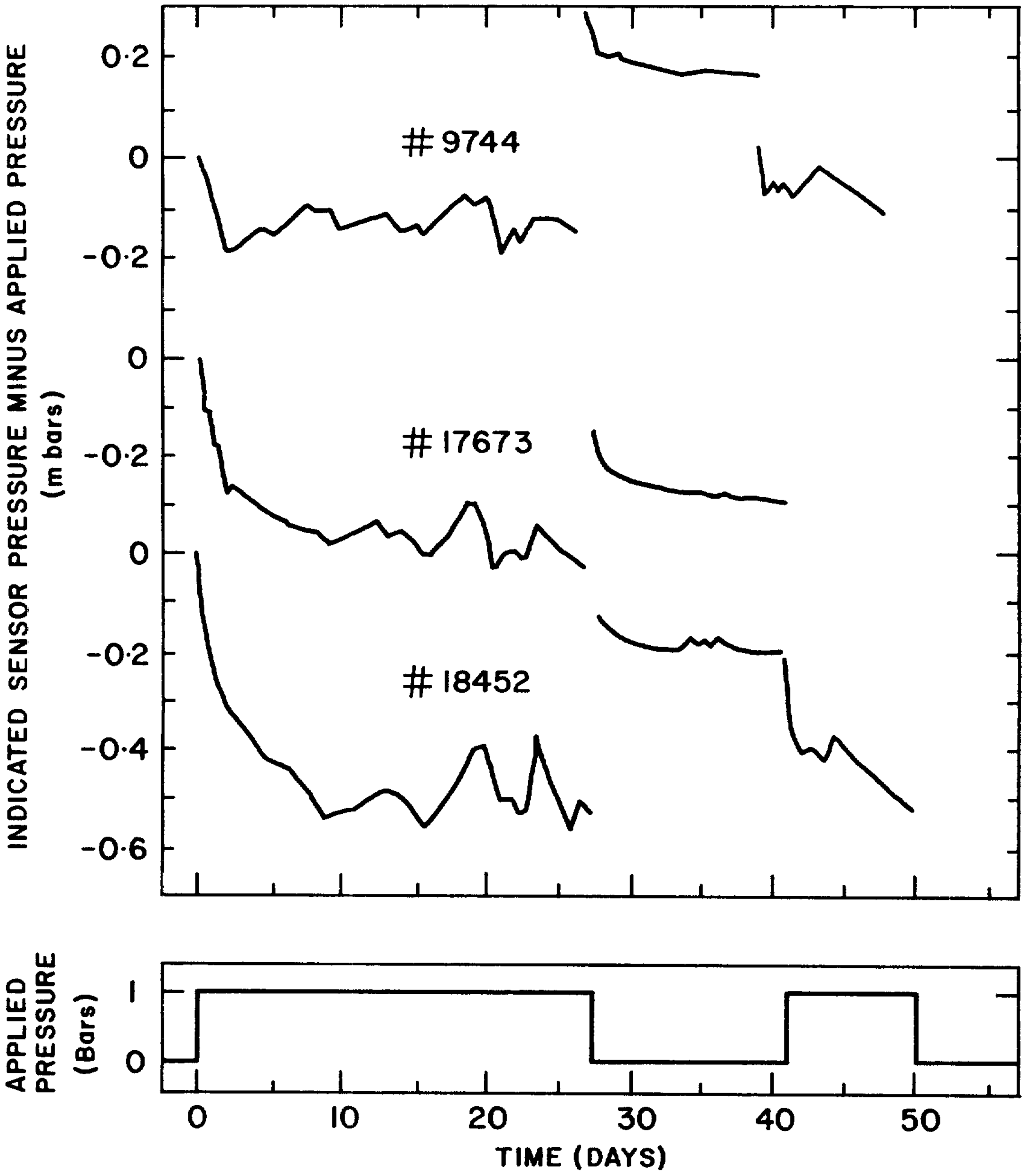


Fig 7. Stability of the 2 Bar differential Digiquartz pressure transducer at 20°C when alternately pressurised to 1 Bar and depressurised to atmospheric pressure.

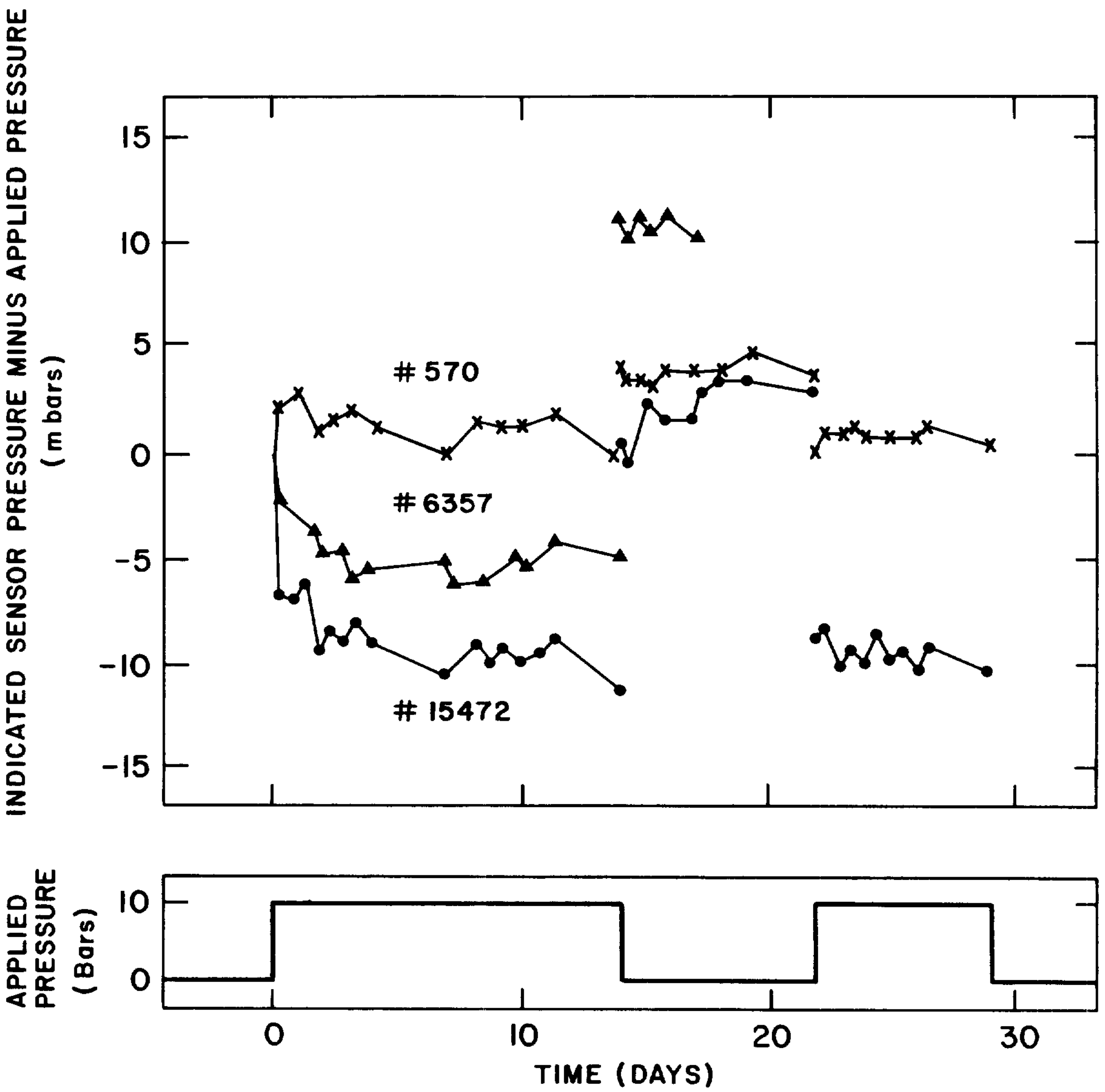


Fig 8. Stability of the 0-27 Bar absolute Digiquartz pressure at 20°C when alternately pressurised to 10 Bar and depressurised. The atmospheric pressure signal has been removed from the data along with any temperature effects.

0-35 °C twenty times, revealed no change in the exponential character of the drift.

Pressurising the transducers to 2 Bar produced the same exponential drift curves as before but the magnitude of the drift had increased from the 1 Bar values of between -0.1 to -0.5 mb, to between -0.3 and -0.8 mb at 2 Bar. Subsequent depressurisations show that the output settled down to the values attained during previous depressurisations.

A similar experiment was carried out with three absolute transducers. One of these, #570 (Depth Sensor Model), was of an earlier design and incorporated internally pressurised bellows, whereas transducers #6357 (housed in WLR 500) and #15472 were fitted with externally bellows. #570 and #6357 had been in use on many occasions whilst #15472 was a new sensor which had not been deployed.

In Figure 8 the drift in output over a period of 30 days was obtained by removing barometric pressure changes, temperature related effects, and finally correcting the data to 10 Bar absolute. The results of depressurisation to 1 Bar absolute are also shown.

The depth sensor #570 shows a slight trend towards higher pressure of 1-2 mbs and on depressurisation produces a positive shift in output of 3 mbs. Subsequent repressurisation resulted in hardly any drift. Transducers #6357 and #15472 both drifted exponentially towards lower pressure by -5 and -10 mbs respectively. On depressurisation #6357 (WLR 500) showed a shift in output of +12 mbs and indicates that all is not well with this particular transducer. Its previous history reveals an output shift of -45 mbs after deployment at 20 Bar, where it suffered damage from being trawled and subsequently washed ashore in Norway. With #15472, on depressurisation the output drifts exponentially to approximately 4 mbs above its initial value but on repressurisation there is no exponential drift and the output settles down to the static value attained in the first pressurisation.

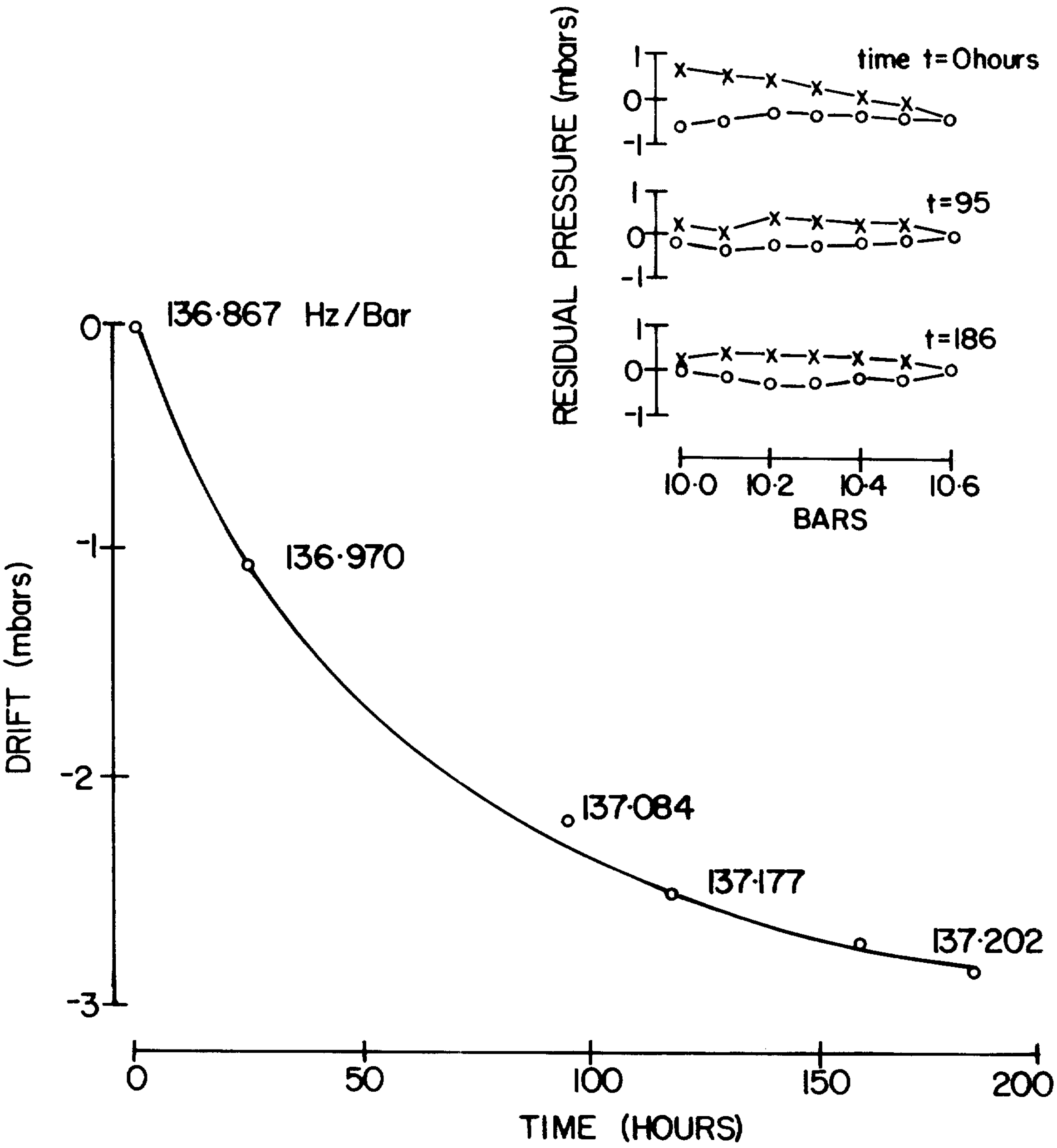


Fig 9. Drift and changes in primary sensitivity which occur when a 27 Bar absolute Digiquartz (#15472) is pressurised to 10 Bars absolute at a constant 20°C. The inset shows the non-repeatability and hysteresis when the transducer is calibrated over a 0.6 Bar pressure range at various points on the drift curve.

It is interesting to note that if the absolute transducers are kept at constant temperature, they show exponential drift during the first pressurisation but not during further repressurisations, unlike the differential transducers.

The positive shifts in output at 1 Bar absolute are sufficient to account for part of the change presented in Table 3 but the shifts in output at higher pressures, obtained under laboratory conditions, are in the opposite sense to those observed in Table 3.

One of the main problems generated by sensor drift, especially for the absolute transducers, is in the calibration procedure. Calibrations usually take only a few hours to perform and it is unfortunate that during this time the drift rates are at a maximum. The primary sensitivity derived from the calibration equation at the beginning of the drift process may be different from that obtained from the instrument which has had its drift removed by pre-pressurisation. This is illustrated in Figure 9 where #15472 was kept at constant temperature and pressurised to 10 Bar absolute. Several calibrations, over a 0.6 Bar pressure range were carried out at various times throughout the experiment. Although this particular transducer only drifted by -3 mbs during the 200 hour period, the primary sensitivity increased by 0.24%. As a consequence, using the initial calibration equation to process the deployment data means that pressure changes are likely to read high by 0.24%. This problem gets worse if high drift sensors are used. One point to note from Figure 9 is that the hysteresis does not decrease as the transducer drift settles down, but the non-repeatability which is obviously linked to the drift, is almost eliminated.

5.6 Common mode line pressure effect.

When differential transducers are used for oceanographic measurements the common mode line pressure is the barometric signal. Experiments carried out in

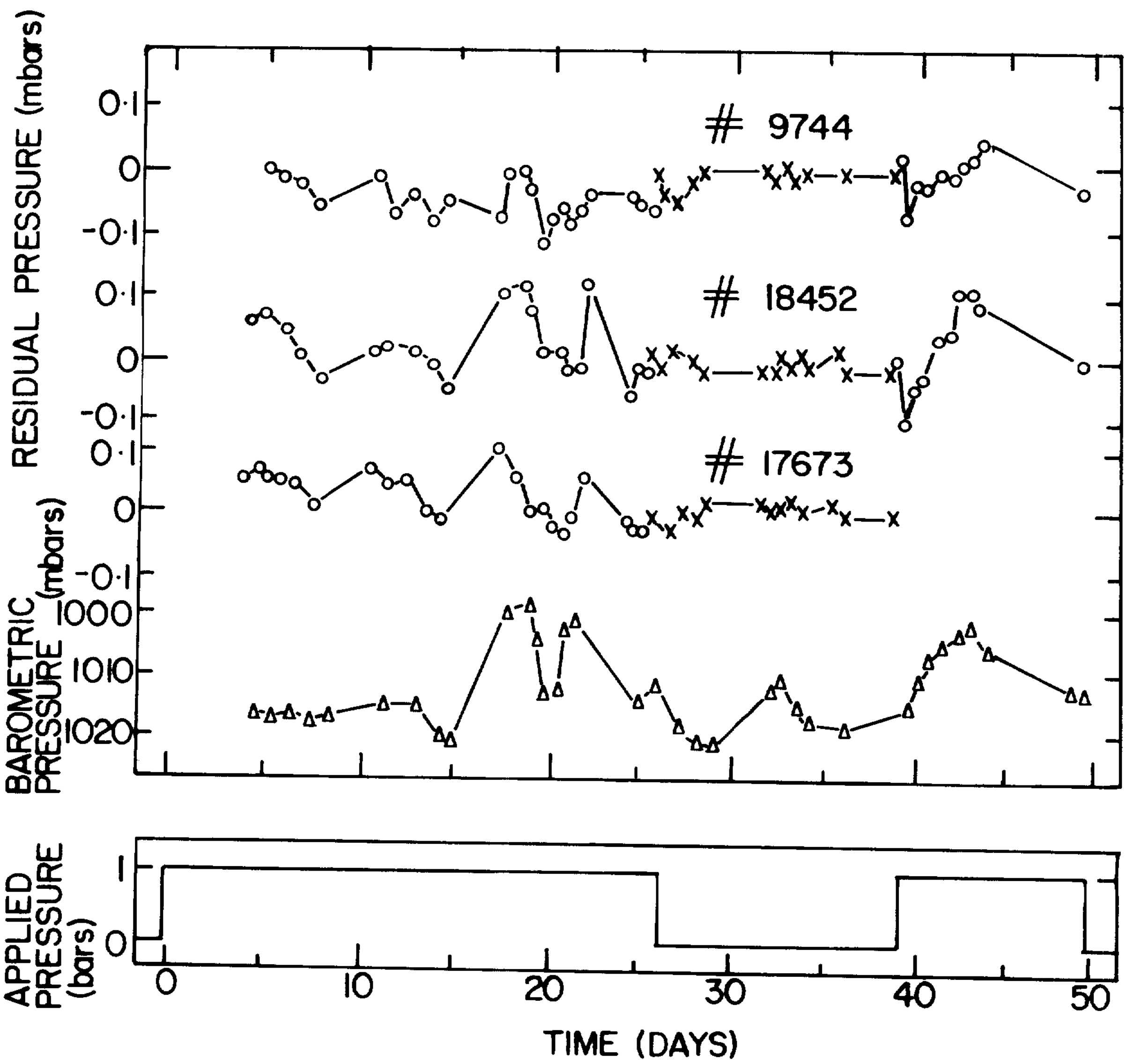


Fig 10. Common Mode Line Pressure Effect associated with the 2 Bar differential Digiquartz at 1 Bar applied pressure.

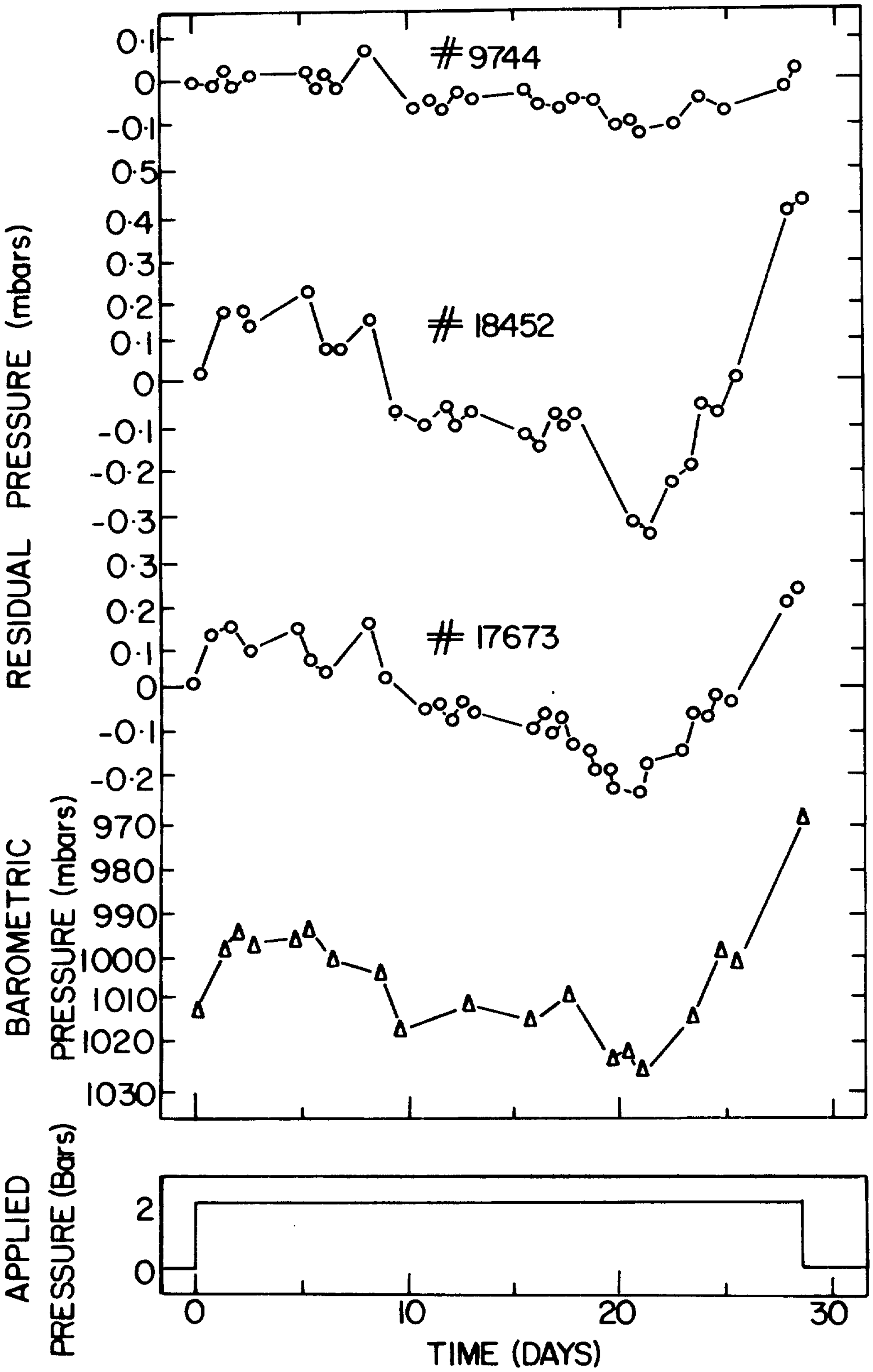


Fig 11. Common Mode Line Pressure Effect associated with the 2 Bar differential Digiquartz at 2 Bar applied pressure.

the laboratory show that some transducers have signals in the output which are induced by the changing barometric pressure.

In Figures 10 and 11 the residual pressure data has been derived by removing the exponential drift and DC offsets from the original temperature corrected pressure data.

The residual pressure data at 1 Bar and 2 Bar show that in two out of the three sensors there is a direct correlation with the changing barometric pressure signal. At zero pressure, i.e. with both ports vented to atmoshpere, there is no correlation, as expected.

At 1 Bar #18452 and #17673 show an approximate +0.2mb change in output for a 20mb drop in barometric pressure, with #9744 exhibiting little response. At 1 Bar, approximately 1% of the change in barometric pressure is present in the output. At 2 Bar this increases to 1.4% for #18452 and #17673 with #9744 again showing little response.

The behaviour of the transducers can be explained as follows. Increasing the input pressure decreases the effective area of the bellows (this is shown to be the case with internally pressurised bellows BUSSE 1978) and since the two bellows are now of unequal effective area a force is exerted on the suspension arm and transmitted to the quartz crystal beam thereby decreasing its resonant frequency. Hence, calibrations performed at widely different barometric pressures will produce different values for the primary sensitivity whilst the zero pressure signal remains unchanged.

5.7 Shock.

Drift experiments carried out in laboratory indicate that changes in transducer output are generally towards a lower pressure. Also, because transducers #4132,4143,4161,WLR 444 and WLR 445 were relatively new the ageing processes would be expected to give a positive change in output during the first few months of use. Positive changes are in fact observed, but much larger in magnitude than the combined processes just mentioned would suggest. The case history of nearly all the absolute transducers reveal that they have been trawled along the sea bed or, in some cases accidently dropped several metres to the sea surface. The evidence available suggests that even though the instruments are shock mounted they are susceptible to damage, a case in point being the history of WLR 500 (#6357).

With differential WLR instruments no such damage is observed because they are usually installed in much safer environments.

5.8 Transducer orientation

Figure 12 shows the effects of orientation on the outputs of two differential transducers, with either air or oil filed tubes, along with an absolute transducer housed in a WLR instrument. As expected the change in output reflects the presence of oil in the tubes but there is an additional effect which shows up in the case of the differential transducers with air filled tubes. This orientation effect, possibly present in many of the transducers, is a consequence of the balance weights being slightly mismatched. This leads to the centre of mass of the transduction system being shifted slightly away from the centre of the flexible pivot point. The effect on the output of #14816 is to change the output by ±0.05 mb when rotated about its most sensitive axis.

The data implies that significant errors will occur between calibrations if allowances are not made for instrument orientation.

6. CONCLUSIONS.

With the differential Digiquartz transducers it is found that differences in the calibrations over several years can mostly be accounted for in terms of common mode line pressure effects, whereas changes in the zero pressure output are a result of the mechanical instability of the bellows.

The exponential drift that can occur is shown to be reversible and has a time

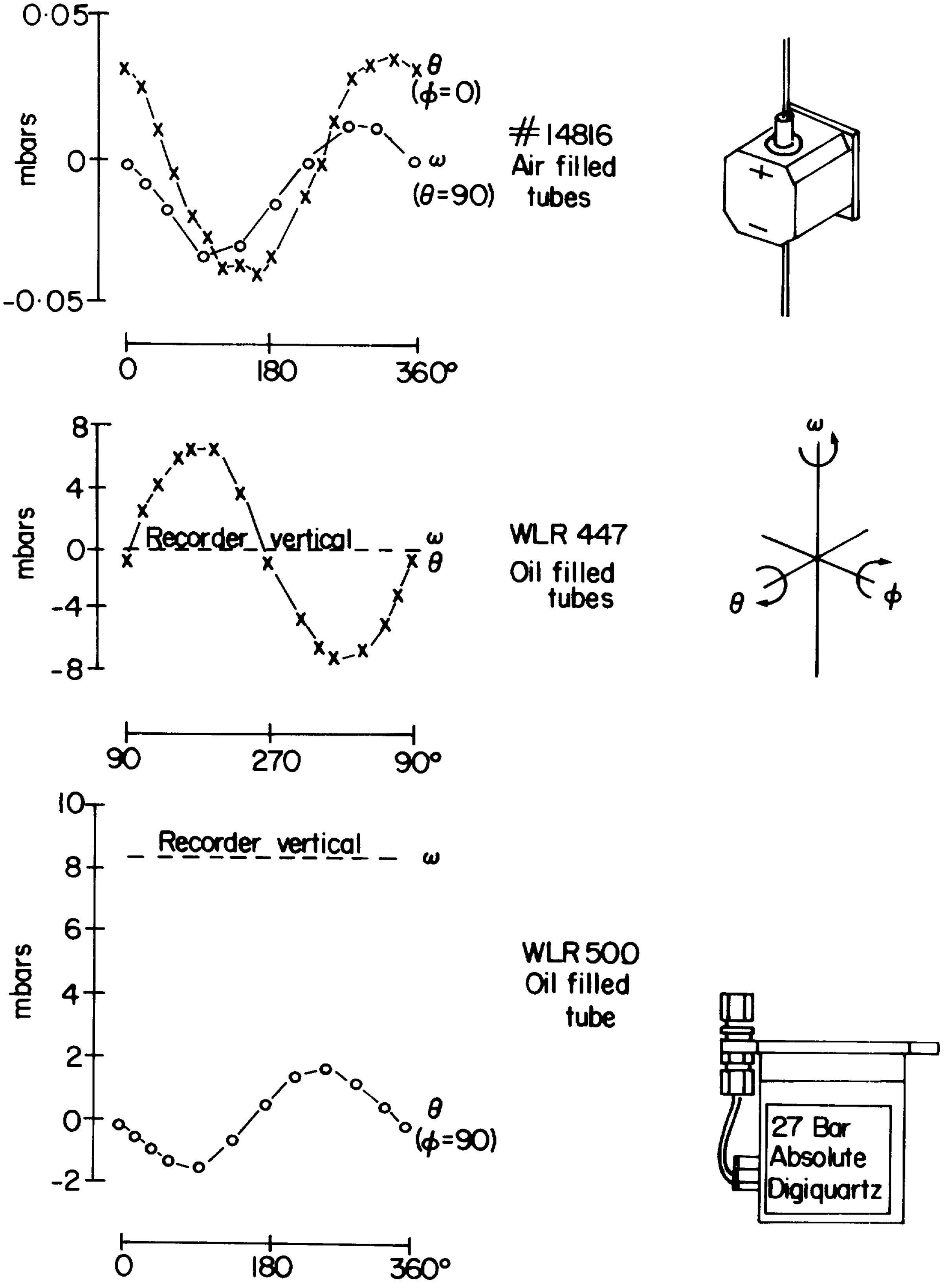


Fig 12. Effect of orientation on the output from a 2 Bar differential Digiquartz transducer (#14816), a differential Water Level Recorder (WLR 447) and a 27 Bar absolute Water Level Recorder (WLR 500).

constant of approximately 40 hours. Thus, datum shifts will occur when the transducer is deployed, the magnitude of which will depend on the particular transducer and the differential pressure. For example, shifts in output up to -0.9 mbs can be expected at 2 Bar and between -0.1 and -0.5 mb at 1 Bar.

Common mode line pressures will also generate a low frequency residual signal which is a function of two variables, namely the barometric pressure change and the differential line pressure. The evidence suggests some form of quadratic relationship between the common mode line pressure effect and the applied pressure.

Datum instability can also be a result of not fitting a high enough order polynomial to the calibration data. Shifts in output of 0.5 mb can be expected as a result of replacing one transducer with another (Figure 2).

The orientation of the transducer both during calibration and deployment needs to be taken into account and a strict calibration procedure adhered to.

With the absolute transducers the situation is in some ways better. The use of externally pressurised bellows seems to have improved the transducers performance. The limited amount of evidence suggests that at constant temperature, the exponential short term drift is not reversible. With this in mind it is a good idea to pre-pressurise the transducer for several days prior to calibration and then perform the calibration over the range likely to be encountered during deployment.

Pre-ageing the absolute and differential transducers by leaving them powered up for a few weeks prior to the first calibration is also implied.

In summarizing, the differentials and low pressure absolute Digiquartz exhibit extremely good long term stability but suffer from short term instability which leads to initial drift and is caused by the mechanics of the bellows (WEARN and LARSON 1982). Improvements in the design of the bellows would probably lead to an improved overall performance.

If the instruments are to be used as shore based pressure recorders for monitoring long term changes in sea level elevations, then a programme of in-situ calibrations (BANASZEK 1985) needs to be undertaken to eliminate datum shifts. In the laboratory great care should be taken in the calibration procedure and due account must be taken of the sensor characteristics when processing the deployment data.

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