ESSO AUSTRALIA LTD.

TUNA #4

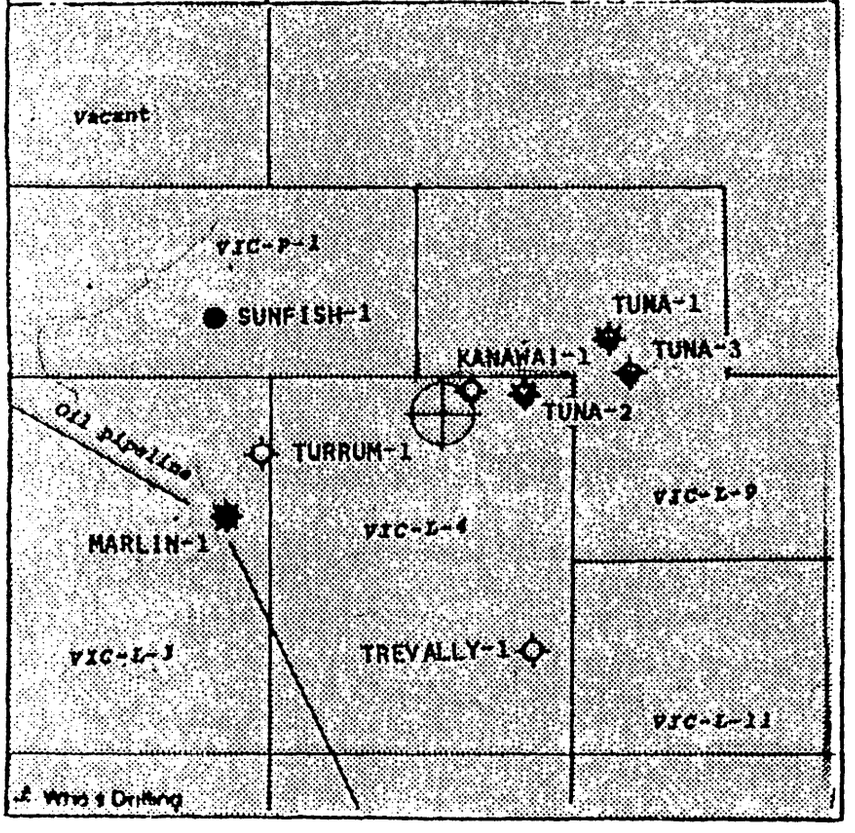
AUSTRALIA VELOCITY SURVEY REPORT.

SONIC CALIBRATION REPORT

COMPANY	:	ESSO AUSTRALIA LTD.
WELL	:	TUNA #4
LEASE	:	VIC-L-4
FIELD	:	WILDCAT
COUNTRY	:	AUSTRALIA
COORDINATES	:	38DEG. 11' 20.93"S 148DEG. 22' 08.39"E
RIG	:	SOUTHERN CROSS
ELEVATIONS	:	GROUND LEVEL AT -60.0M AMSL DERRICK FLOOR AT 20.7M AMSL
DATE OF SURVEY	:	8TH JULY 1984

TUNA-4

LOCATION	CO-ORDINATES 38°11'20.93"S 148°22'08.39"E
	PERMIT Vic-L-4
	TD 3321 m
	WD 60 m
	RT
	KB
SCALE	0 10 20 km



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SUMMARY

A velocity check shot survey was conducted in the Tuna #4 well on July 8th 1984. Eighteen levels were shot using an airgun source and the results from these shots have been used in the calibration of the sonic log.

All shot times and the calibrated sonic times have been corrected to a nominal Mean Sea Level Datum.

DATA ACQUISITION

FIELD EQUIPMENT

Energy Source	:	Bolt airgun (model 1900B) 200 cu.in.
Source Offset	:	46.3m
Source Depth	:	9.1m below MSL
Source Azimuth	:	50 Deg.
Reference Sensor	:	Accelerometer
Sensor Offset	:	46.3m
Sensor Depth	:	9.1m below MSL
Downhole Geophone	:	Geospace HS-1 High temperature (350 Deg. F), Coil Resistance 225 + 10%, Natural Frequency 8-12 Hz, Sensitivity 0.45 V/in/sec. Maximum tilt angle 60 Deg. Min.

Recording Instrument

Recording was made on the Schlumberger Computerized Service Unit (CSU) using LIS format recorded at 1ms sample interval.

PROCESSING PARAMETERS

Seismic Reference Datum (SRD)	:	Mean Sea Level
Elevation SRD	:	Mean Sea Level
Elevation Derrick Floor	:	20.7m AMSL
Elevation Ground Level	:	-60.0m AMSL
Well Deviation	:	0 Deg.
Total Depth	:	3322m below DF
Sonic Log Interval	:	221 - 3321m below DF
Density Log Interval	:	795 - 3321m below DF

SHOT DATA

Level Depth (m below KB)	Stacked Shots	Rejected Shots	Quality	Comment
3300	6	1	Good	
3030	4	0	Good	
3000	5	2	Good	
2696	0	5	Poor	Omitted
2685	4	0	Good	
2470	7	0	Good	
2400	4	0	Good	
2200	7	1	Good	
2040	5	0	Good	
1800	4	0	Good	
1565	5	0	Good	
1371	3	0	Good	
1200	3	0	Good	
1000	4	0	Fair	Distorted
800	27	0	Fair	Distorted
600	9	0	Poor	Noisy
414	7	0	Poor	Noisy/Omitted
0	13	0	Good	

A total of 18 check levels were shot with the number of stacked and rejected shots for each level being shown in the table above.

The general data quality was fair to good with a number of levels near the top of the well affected by noise distortions probably caused by casing arrivals.

Consequently, after comparison with the good signals at lower levels, the levels at 800m and 1000m below DF have been timed using the second visible break on the geophone signal. The check levels at 414m and 600m below DF are more severely distorted and the times obtained from these levels have not been used in the computations or calibration of the sonic log. However after consultation with ESSO AUSTRALIA LTD it was decided to model an average velocity of 2075m/s from MSL to 600m below DF, hence a false "observed" time has been input at 600m in the computations.

No good data was available for stacking at the 2696m check level.

A plot of the stacked check shot data (Figure 1) has been included in the report.

GUN OFFSET

The shot at the surface is normally used to calculate the gun offset from the wellhead. Using the measured transit time of 26ms and water velocity of 1480m/s a gun offset distance of 38.5m was calculated. However this distance disagreed with that measured by the field engineer of 46.3m. The measured distance was considered more accurate and consequently has been used in the computations.

SONIC CALIBRATION

Purpose: To adjust the sonic log using the vertical times obtained at each check level.

Method: A "drift" curve is obtained using the sonic log and the vertical check level times. The term "drift" is defined as seismic time (from check shots) minus sonic time (from integration of edited sonic). Commonly the word "drift" is used to identify the above difference, or to identify the gradient of drift versus increasing depth, or to identify a difference of drift between two levels.

The gradient of drift, that is the slope of the drift curve, can be negative or positive.

For a negative drift $\frac{\Delta \text{drift}}{\Delta \text{depth}} < 0$, and the sonic time is greater than the seismic time over a certain section of log.

For a positive drift $\frac{\Delta \text{drift}}{\Delta \text{depth}} > 0$, and the sonic time is smaller than the seismic time over that section of log.

The drift curve, between two levels, is then an indication of the error on the integrated sonic or an indication of the amount of correction required on the sonic to have the TTI of the corrected sonic match the check shot times.

Two methods of correction to the sonic log are used.

(a) Uniform or block shift.

This method applies a uniform correction to all sonic values over the interval. This uniform correction is applied in the case of positive drift and is the average correction represented by the drift curve gradient expressed in μs/ft.

(b) ΔT Minimum

In the case of negative drift a second method is used, called Δt minimum. This applies a differential correction to the sonic log, where it is assumed that the greatest amount of transit time error is caused by the lower velocity sections of log. Over a given interval the method will correct only Δt values which are higher than a threshold, the Δt minimum. Values of Δt which are lower than the threshold are not corrected. The correction is a reduction of the excess of Δt over Δt minimum, $\Delta t - \Delta t$ min.

$\Delta t - \Delta t$ minimum is reduced through multiplication by a reduction coefficient which remains constant over the interval. This reduction coefficient, named G, can be defined as:

$$G = 1 + \frac{\text{Drift}}{\int(\Delta t - \Delta t \text{ minimum})\,dZ}$$

Where drift is the drift over the interval to be corrected and the value $\int(\Delta t - \Delta t \text{ minimum})dZ$ is the time difference between the integrals of the two curves Δt and Δt minimum, only over the intervals where $\Delta t > \Delta t$ min.

Hence the corrected sonic: $\Delta t = G(\Delta t - \Delta t \text{ min}) + \Delta t \text{ min}$.

SONIC CALIBRATION PROCESSING

OPEN HOLE LOGS

Both the sonic and density logs used in this report have been edited prior to input into the WST chain. The sonic log has been edited for noise spikes over the following intervals 2714.5 - 2715.5m, 2720 - 2721m, 2784 - 2785m below DF. The density log has been edited in areas of washout, notably 1921 - 1923m, 1929 - 1930m, 2441 - 2443m, 2640 - 2643m, 2647 - 2650m, 2699 - 2730m, 3010 - 3011.5m, 3230.5 - 3231.5m and 3314.5 - 3315.5m.

CORRECTION TO DATUM

Seismic reference Datum (SRD) is at Mean Sea Level. The airgun was positioned 9.1m below SRD.

VELOCITY MODELLING

Due to poor check shot data at and above 600m below DF an average velocity of 2075m/s from seabed to 600m below DF was supplied by ESSO AUSTRALIA LTD. Using this velocity an interval velocity of 1593m/s was modelled between MSL and the top of the sonic at 221m below DF.

SONIC CALIBRATION RESULTS

The top of the sonic log is chosen as the origin for the calibration drift curve. All drift measurements are relative to this point.

The drift curve indicates a number of corrections to be made to the sonic log. Block shifts of 1.37 us/ft and 4.26 us/ft have been applied over the intervals 846 - 1559 m and 1559 - 2467m below DF respectively. A zero shift has been applied from 2467 to 2727m and differential shifts using delta-t minimum values of 108.93 us/ft and 61.69 us/ft have been applied over the intervals 221 - 846m and 2727 - 3321m respectively (Depths below DF).

The adjusted sonic curve is considered to be the best result using the available data.

GEOGRAM PROCESSING

Geograms were generated using zero and minimum phase Ricker wavelets with frequencies at 20, 25, 30 and 35 Hz.
The presentations include both normal and reverse polarity at 7.5in/sec.

Geogram processing produces synthetic seismic traces based on reflection coefficients generated from sonic and density measurements in the well-bore. The steps in the processing chain are the following:

Time to depth conversion
Generate reflection coefficients
Generate attenuation coefficients
Choose a suitable wavelet
Convolution
Output

TIME TO DEPTH CONVERSION

Open hole logs are recorded from bottom to top with a depth index. This data is converted to a two-way time index and flipped to read from top to bottom in order to match the seismic section.

REFLECTION COEFFICIENTS - ATTENUATION COEFFICIENTS

Primaries:

Sonic and density data are averaged over chosen time intervals (normally 2 or 4ms intervals). Reflection coefficients are then computed using:

$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1}$$

where ρ_1 = density of the layer above the reflection interface
ρ_2 = density of the layer below the reflection interface
v_1 = compressional wave velocity of the layer above the reflection interface
v_2 = compressional wave velocity of the layer below the reflection interface

This computation is done for each time interval to generate a set of primary reflection coefficients without transmission losses.

PRIMARIES WITH TRANSMISSION LOSS;

Transmission loss on two-way attenuation coefficients are computed using:

$$A_n = (1-R_1^2)(1-R_2^2)(1-R_3^2)\ldots(1-R_n^2)$$

A set of primary reflection coefficients with transmission losses is generated using:

$$\text{Primary}_n = R_n A_{n-1}$$

PRIMARIES PLUS MULTIPLES:

Multiples are computed from these input reflection coefficients using the transform technique from the top of the well to obtain the impulse response of the earth. The transform outputs primaries + multiples.

MULTIPLES ONLY:

By subtracting previously calculated primaries from the above result we obtain multiples only.

WAVELET

A theoretical wavelet is chosen to use for convolution with the reflection coefficients previously generated.

Choices available include:

Klauder wavelet
Ricker zero phase wavelet
Ricker zero phase wavelet
Ricker minimum phase wavelet
User defined wavelet

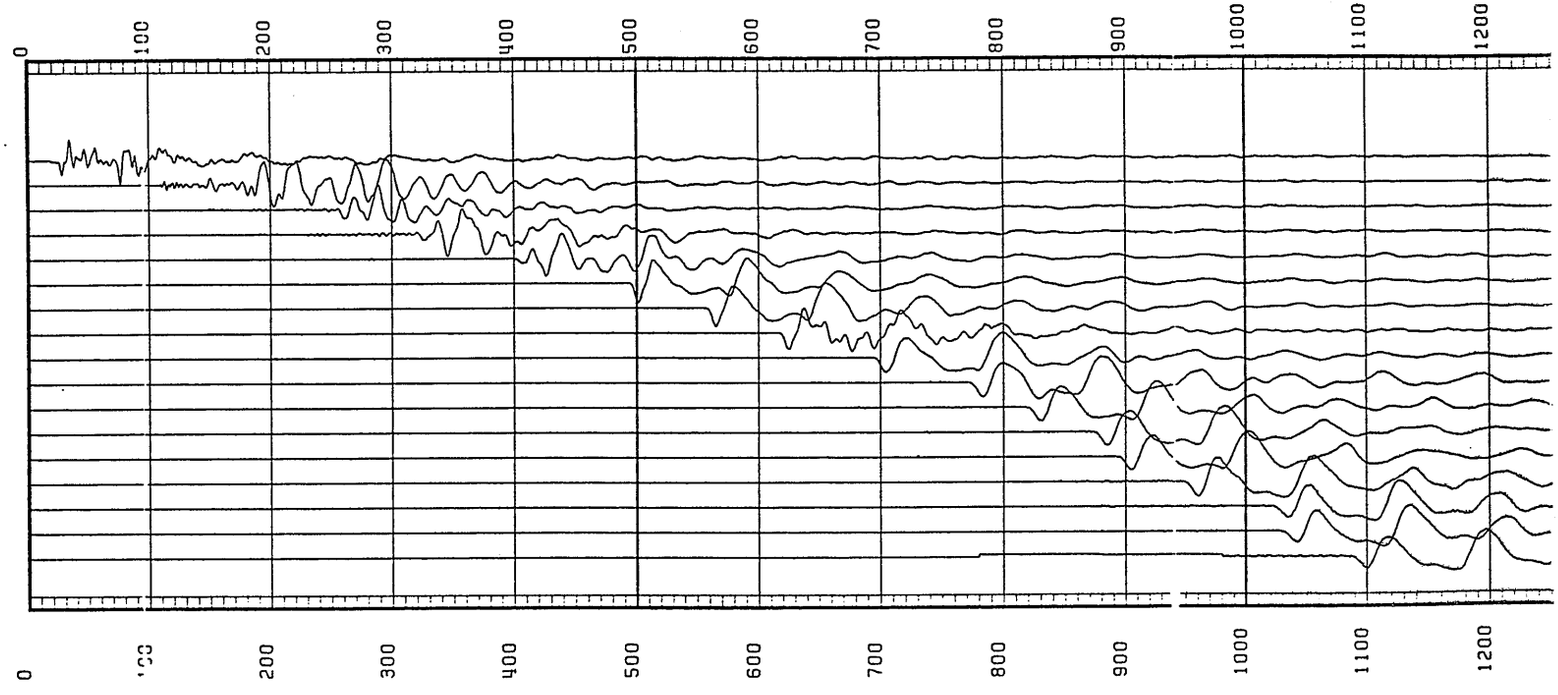
All wavelets can be chosen with or without butterworth filtering and with user defined centre frequencies. Polarity conventions are shown in Figure 2. These Geograms were generated using zero and minimum phase Ricker wavelets.

CONVOLUTION

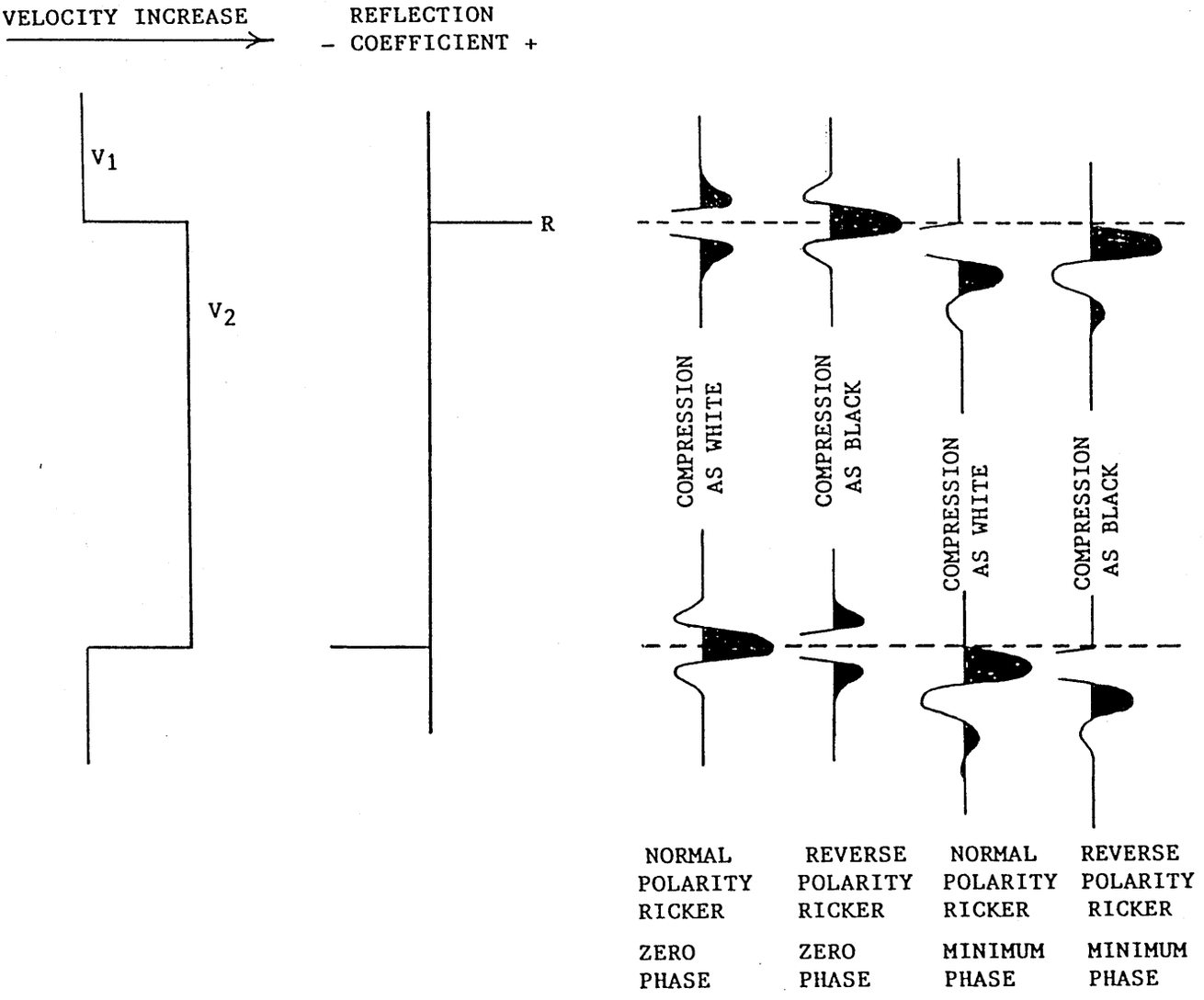
Standard procedure of convolution of wavelet with reflection coefficients. The output is the synthetic seismic data.

FIGURE 1 : STACKED CHECK SHOT DATA

LEVEL	DEPTH M	TIME S	PEAK/PEAK
19	0.0	0.026	266.93
18	414.1	0.179	39099.67
17	600.1	0.257	20359.28
16	800.1	0.341	10589.10
15	1000.0	0.419	10957.60
14	1200.1	0.496	7399.00
13	1371.0	0.559	5578.00
12	1565.0	0.619	4701.83
11	1800.0	0.697	2491.00
10	2040.0	0.774	1649.83
9	2200.0	0.821	1289.62
8	2400.0	0.876	1335.20
6	2470.0	0.896	961.38
5	2685.0	0.951	868.40
3	3000.0	1.024	913.33
2	3030.0	1.031	958.80
1	3300.0	1.090	634.86



SCHLUMBERGER WAVELET POLARITY CONVENTION



NOTE: WAVELET DISPLAYED UNDER GEOGRAMS ARE FOR A REFLECTION COEFFICIENT OF -0.5

FIGURE 2

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WELL SEISMIC SERVICE COMPUTATION REQUEST

COMPANY: ESSO AUST. CONTACT: _____

WELL: TUNA #4 SUITE 4 - RUN 1

FIELD/COUNTRY: OUTPOST/VICTORIA

LOCATION/DIVISION: GIPPSLAND BASIN

DATE WST JOB: 8TH JULY, 1984

DATE SENT: 17TH JULY, 1984

BY: _____

NUMBER OF COPIES OF RESULTS (CLIENT)

PRODUCT	REPORTS	PLOT TRANSP.	PLOT PRINT	TAPE
WSE				
WSC	6	1	6	1
GEO	6	1	6	
VSP				

DATA SUPPLIED FOR INTERVALS TO BE PROCESSED

	FROM	TO
A. LOGS : DENSITY	3322m	793.5
SONIC	3321m	204m
B. SHOTS	3300m	0.0m

UNITS: FEET ☐ METRES ☒

CLIENT TAPE: FORMAT: SEGY ☐ LIS ☒

DENSITY: 800 BPI ☐ 1600 BPI ☒

SONIC CALIBRATION BY WST (WSC)

URGENT? YES ☒ NO ☐

IS A WELL SEISMIC EDIT (WSE) REQUESTED? YES ☒ NO ☐

(WSE IS RECOMMENDED WHERE FIELD STACK QUALITY IS AFFECTED BY BAD HOLE CONDITIONS)

REQUESTED TIME ORIGIN (SRD) _____ METRES ABOVE/BELOW MEAN SEA LEVEL (MSL)

STATIC CORRECTION TO BE APPLIED : –

_____ MILLISECONDS FROM GROUND LEVEL **OR**

LAYER	VELOCITY	FROM	TO
1			
2			
3			

TRUE VERTICAL DEPTH (TVD) CORRECTION? YES ☐ NO ☒ (TVD IS RECOMMENDED IF DEVIATION EXCEEDS 5°)

DEVIATION DATA SUPPLIED? YES ☐ NO ☒

11 INCH WSC DISPLAY DEPTH SCALES TO BE USED (UP TO TWO) 1/5000 ☐ 1/1000 ☐ OTHER ☐

22INCH WIDE TIME/DEPTH DISPLAY SPECIAL TIME FUNCTION? (T – DEPTH/VELOCITY) YES ☐ NO ☐ VELOCITY ☐

22 INCH WIDE GEOLOGICAL INTERVAL VELOCITY DISPLAY? YES ☐ NO ☐ GEOLOGICAL MARKERS SUPPLIED ☐

SPECIAL SCALES TO BE USED? SPECIFY

GEOGRAM

URGENT? YES ☒ NO ☐

FREQUENCY TEST TO BE SUPPLIED BEFORE FINALIZATION (8 BAND WIDTHS) YES ☐ NO ☐

FINAL GEOGRAM PARAMETERS : –

(ONE GEOGRAM INCLUDES DISPLAYS IN BOTH POLARITIES FOR EACH OF, PRIMARIES, PRIMARIES + MULTIPLES, PRIMARIES WITH TRANSMISSION LOSS, MULTIPLES ONLY FOR THE CHOSEN WAVELET AND T.V.F.)

WAVELET	FREQ.
KLAUDER ☐	
MIN PHASE ☐	
ZERO PHASE ☐	
OTHER: ☐	

	T. LOW	T. HIGH	F. LOW	F. HIGH
T.				
V.				
F.				

SCALE IS 10 CM/SEC + ONE OTHER – SPECIFY ☐

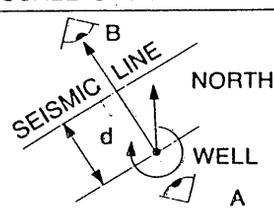
DIP OPTION YES ☐ NO ☐

SEISMIC LINE NUMBER _____

(ENCLOSE WELL LOCATION MAP VERSUS SEISMIC LINE)

DISTANCE BETWEEN TRACES _____

SECTION PERSPECTIVE: SEEN FROM A ☐ FROM B ☐



d _____

∝ _____

∝ (CLOCKWISE)

SPECIAL REQUESTS: _____

VERTICAL SEISMIC PROFILE

URGENT? YES ☐ NO ☐

UP TO 3 VELOCITY FILTER TESTS WILL BE SENT PROVISIONALLY

SPECIFY NUMBER OF TRACES IN WINDOW REQUIRED 3 ☐ 5 ☐ 7 ☐ 9 ☐ 11 ☐

TIME VARIANT FILTER (TVF) TO BE APPLIED ON FINAL DISPLAY : –

SCALE IS 10 CM/SEC + ONE OTHER. SPECIFY ☐

SPECIAL REQUESTS?

TIME 1	TIME 2	FLOW	F. HIGH

ENCLOSE SEISMIC SECTION. INDICATE RELATION TO WELL ON A DIAGRAM

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WELL SEISMIC SERVICE FIELD REPORT

COMPANY	WELL	DATE	LOCATION	ENGINEER	WITNESSED BY
ESSO AUSTRALIA	TUNA #4	8 JULY 1984	SOUTHERN CROSS	DAWSON/MANAN	J. KULLA/J. ROACHE

FEET ☐ METRES ☒ | JACK UP ☐ SHIP ☐ | PLATFORM ☐ SEMI-SUB ☒ | WEATHER: SLIGHT BREEZE

SCHLUMBERGER ZERO	DF	AT ELEVATION	20.7m	RELATIVE TO MEAN SEA LEVEL (M.S.L.)
LOG MEASURED FROM		AT ELEVATION		RELATIVE TO SCHLUMBERGER ZERO
DRILLING MEASURED FROM	DF	AT ELEVATION	0.0m	RELATIVE TO SCHLUMBERGER ZERO

SOURCE

GUN TYPE WATER ☐ AIR ☒
VOLUME 1 x 200 CU INCHES
PRESSURE 140 BARS
VIBRATOR TYPE -
SWEEP LENGTH - SECONDS
FROM - HZ TO - HZ

TIDEL INFORMATION

	DISTANCE	HOUR	DATE
TIDE LEVEL TO M.S.L. (REF. FOR	0	17:11	8/7
(RECORD IF LEVEL VARIES HIGH TIDE)	-.5	18:00	8/7
MORE THAN 2 METRES	- 1	19:43	8/7
DURING SURVEY)	-2.5	21:22	8/7
	-3.75	22:54	8/7

CSU SOFTWARE VERSION: 24.2 | MAX. HOLE DEV: 4° AZIM: 15°

NOTE: SHOTS HIGHLY RECOMMENDED AT TD, TOP EACH SONIC, ABOVE AND BELOW BAD HOLE INTERVALS

UNCORRECTED RESULTS Quality: G = Good, P = Poor, U = Unsatisfactory

SHOT NO.	DEPTH	GUN PRESSURE	FILTERS	TRANSIT TIME	HOUR SHOT	FILE	STACK	STACKED SHOTS	QUALITY / REMARKS
1	0.0m	140 BARS	NONE	27.1	16:45	1	2	5 ONLY	MOON POOL SHOT
2	414m	"	"	188.1	17:00	1	3	9,10,11,12,13	CASING NOISE
3	600m	"	"	257.9	17:50	1	4	14,15,16	
4	800m	"	"	324.1	18:00	1	5	17,18,19	
5	3300m	"	"	1090.4	18:45	1	6	22,23,24,26	
6	3030m	"	"	1031.3	19:06	1	7	27,28,29,30	
7	3000m	"	"	1025.1	19:17	1	8	31,34,36,37	
8	2685m	"	"	951.4	19:45	1	9	44,45,46,47	
9	2470m	"	"	896.1	20:09	1	10	53,54,55	
10	2400m	"	"	876.2	20:20	1	11	56,57,58,59	
11	2200m	"	"	821.4	20:33	1	12	61,64,65,67	
12	2040m	"	"	774.3	20:50	1	13	69,70,71,72	
13	1800m	"	"	697.3	21:00	1	14	73,74,75,76	
14	1565m	"	"	619.3	21:10	1	15	77,78,79,81	
15	1371m	"	"	560.1	21:20	1	16	82,83,84	
16	1200m	"	"	496.0	21:25	1	17	85,86,87	
17	1000m	"	"	402.0	21:33	1	18	88,89,90,91	
18	800m	"	"	322.3	22:08	1	19	112,113,114,115	
19	600m	"	"	257.1	22:24	1	20	118,119,120,121	
20	0.0m	"	"	26.4	22:30	1	21	123,124,125,126	

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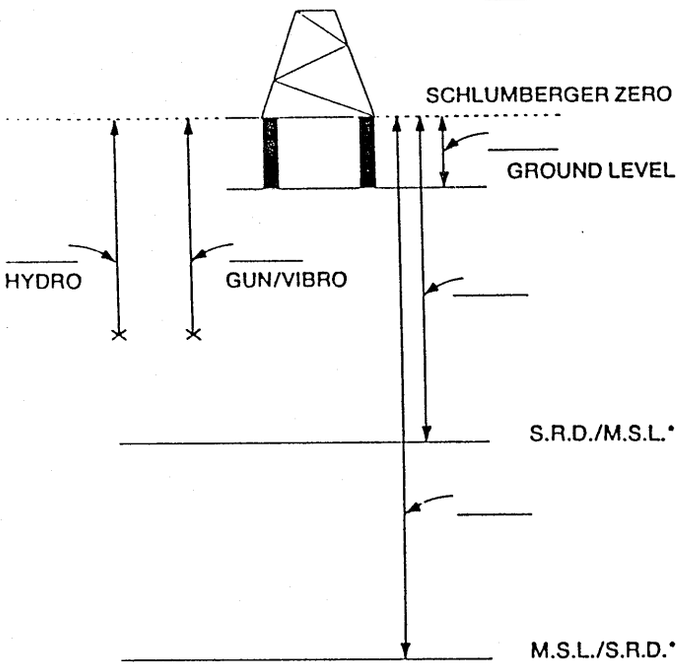
GUN GEOMETRY SKETCH

CLIENT: ESSO AUSTRALIA LTD. WELL: TUNA #4 DATE: 8TH JULY 1984

LAND

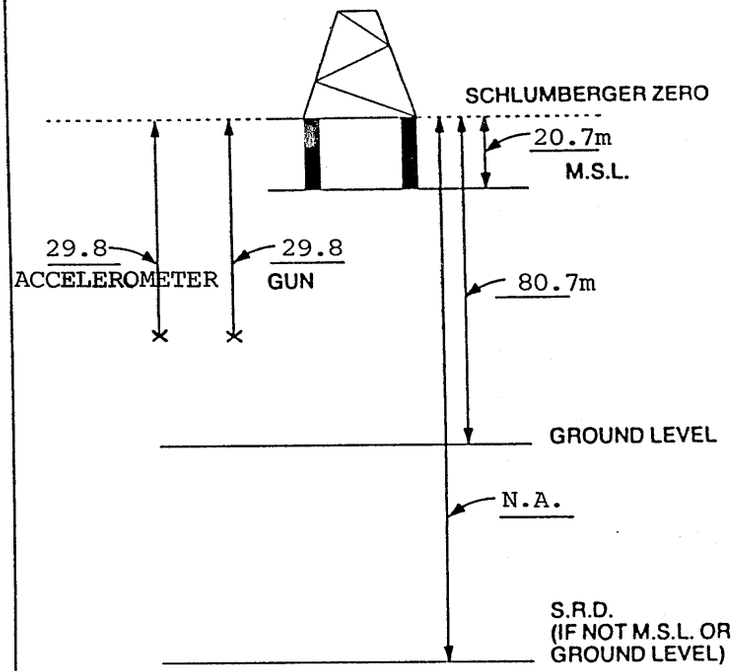


INDICATE ALL DISTANCES RELATIVE TO SCHLUMBERGER ZERO

* DELETE AS APPLICABLE

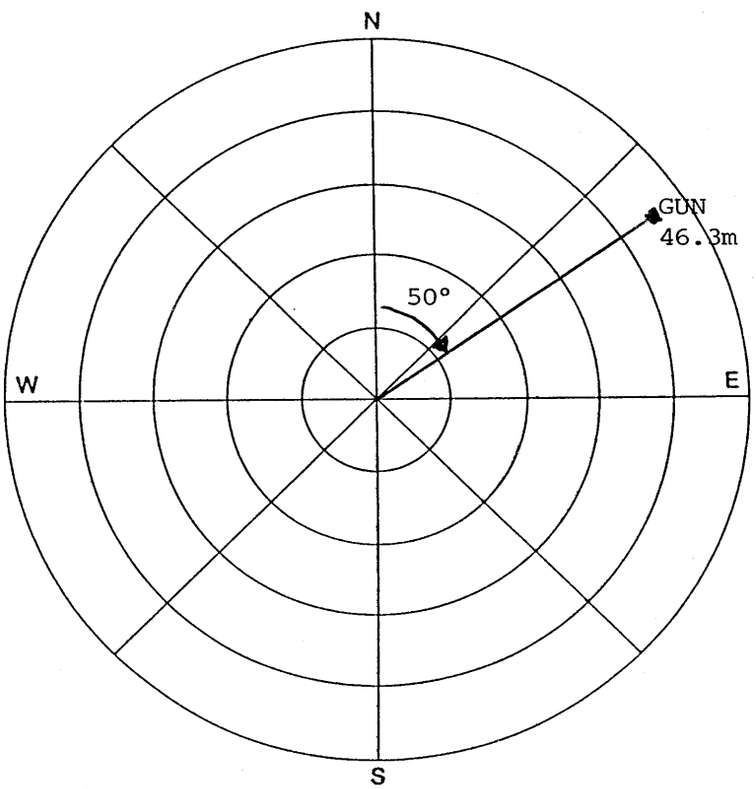
OFFSHORE

XX



INDICATE ALL DISTANCES RELATIVE TO SCHLUMBERGER ZERO

SHOT POS'N	GUN OFFSET	HYDRO OFFSET	GUN DEPTH	HYDRO DEPTH
1	46.3	46.3	9.1	9.1
2				
3				
4				
5				
6				
7				



INDICATE GUN/VIBRO AND HYDROPHONE OFFSET AND AZIMUTH RELATIVE TO NORTH