A SYSTEM FOR ACQUIRING EARTHQUAKE DATA ON OFFSHORE OIL PLATFORMS

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SUMMARY

Shell and its partners have installed a system to measure platform response to earthquakes on a structure 12 miles offshore from Long Beach, California. All measurements are made with triaxial accelerometer packages. Four units are placed at strategic sites at the mudline and on the platform deck. The recording system triggers at 0.01 g. The overall unit response is from .005 g to .300 g. The data will be used to aid in the evaluation of post-earthquake platform conditions and verify and calibrate computer programs for predicting the structure's response to strong earthquakes.

INTRODUCTION AND BACKGROUND

At present, there are no suitable data from offshore sites on strong ground motion. Offshore oil platforms have been designed using data from onshore locations. It is not known whether this ground motion would be greater or less than those offshore because of:

1) Different soil conditions
2) Distance from epicenter
3) Depth of hypocenter
4) Magnitude of the event
5) Effect of the water

To resolve these questions, Shell and its partners have installed an instrumentation system on its Beta field platforms. Figure 1 shows the location of the field and Figure 2 is a photograph of the two platforms already in place. A third platform, in 700 feet of water, will be launched in 1984.

Because of the need to measure platform response in this active earthquake area, special square tubes or chutes were installed on each

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platform on the corner legs. These chutes, designed to be dry, extend from the +12 foot level to the mudline.

A two-part program was started in 1980 to gather the necessary strong motion response. Phase I used one Kinemetrics SMA-2 self-contained sensor package on each platform. See Figure 3. This was an interim data gathering program while Phase II was being designed and built. Phase I has operated satisfactorily since its installation and has served as a backup for the permanent system. No strong motion events have been recorded. However, various platform operations have caused the units to trigger.

Two small earthquakes in the area failed to trigger the system. Neither did the same events trigger onshore seismic stations that were closer to the epicenter.

PHASE II - THE PERMANENT SYSTEM

Overall Design Concepts

The entire Phase II system was designed to be housed on the production platform in the Beta field. It is connected to the drilling platform by a 320 foot bridge. Both structures are located in 260 feet of water. A block diagram of the instrumentation system is shown in Figure 4. The motion sensing system consists of five three-dimensional accelerometer packages. As previously mentioned, two of the units are located on opposite corner legs, at the mudline, in the specially designed chutes. Two others are placed on the same corner legs just above the lower deck. A fifth package was designed to be pushed about 10 feet into the soil midway between the two platforms directly under the bridge. This free field probe has not been installed; however, the insertion device has been built and tested. All of the primary transducer packages contain their own regulated power supply along with line-driver amplifiers and offset voltage adjustments. All components are hard-wired to the remaining signal conditioning and recording equipment.

Mudline Accelerometer Packages

These units consist of a triaxial accelerometer system with electronics housed in a polycarbonate case that is 4.5 inches square and 20 inches long. It can be lowered to the mudline inside a dry square steel tube welded to legs A4 and B1. See Figure 2. Two spring-loaded, nitrogen-released cylinders hold the package secure inside the chute. The selected chutes provide data from opposite diagonals orthogonal to the bridge connecting the two platforms. These chute packages have undergone a substantial evolution over the last 3 years. The original prototype was machined from a solid piece of aluminum stock using many man-hours. The next unit was made of 1/4" aluminum plate welded into a parallelepiped with the accelerometers fitted into a precision mount bolted along the center of the box, inside the box. The working package used sheet polycarbonate for the outer container and an interior mount made from a solid bar of the same material. See Figure 5. A 75% weight reduction was achieved with no loss in strength by using this plastic material. It is also non-corrosive. Figure 6 is a photograph of a chute package.

Before any of the accelerometer packages were installed, a prototype was completely tested on a shake table at UCLA. The test had several purposes:

1) Ensure that the holding system was sufficient to prevent movement under large excitations.

2) Measure the response characteristics over the region of interest and note any anomalies.

3) Ensure that the natural frequency of the package is not in the area of interest.

A piece of square chute material 4 feet long with an inside dimension of 5 inches was clamped on the UCLA shake table. This table consists of a 400-pound, 6-foot by 3-foot rectangular steel grillage that is hydraulically driven in one direction. For the tests, the amplitude was varied from 0.2 g to 1.2 g and the frequencies from 0.5 to 40 Hz. A servo-type ENDEVCO accelerometer Model QA-116-15 was attached to the table to measure its motion. Power was supplied to the accelerometer and the output signal amplified by an ENDEVCO Model SC-116-2M signal conditioning unit. The table hydraulics could be excited by an oscillator for sinusoidal response or by a tape recorder output for earthquake simulation. Two earthquake recordings were available for the table - El Centro 1940 and Taft 1952.

The outputs from the reference accelerometer and the package accelerometer were compared. The chute position was changed to enable testing of all three package accelerometers. Comparisons were made using both sinusoidal and earthquake excitation. Also, the relative displacement between the package and the chute was observed during all these tests.

For each test performed, no differences were noted between the reference and package accelerometers. A comparison of the reference accelerometer signal and package accelerometer signal, indicated similar response over a wide range of frequencies. A comparison using a spectrum analyzer indicated a coherence of 1.0 at the predominant frequencies. The only differences noted were a result of the different types of filters used on the package and the reference accelerometer. At no time did the package move relative to the chute. Finally, no natural frequency of the package was apparent in the frequency region of interest.

The Deck-Mounted Packages

The two deck-mounted accelerometer units are identical to the ones in the chutes. Their steel housing is welded to legs A4 and B1 just above the lowest working deck. See Figure 7. The surface mountings each contain a Kinemetrics vertical trigger which is set at 0.01 g. The power for the chute accelerometers and their signal return is carried by cable in conduit from the signal-conditioning equipment through the deck-mounted accelerometer housing and then by cable in conduit to the top of the chutes. The trigger signal is carried by two wires in the same cable with the deck accelerometer output. Because of safety requirements, these deck-mounted houses are purged with nitrogen and sealed to prevent gas intrusion.

The Signal Conditioning Equipment

The signal-conditioning equipment and the recorders are housed in a six-foot standard rack inside the motor control room. See Figure 8. Each accelerometer signal passes through four electronic components before recording:

Differential receiver amplifier
High pass filter
Adjustable low pass filters
Recorder driver buffer

The overall gain of this system is four. The dynamic range is from 0.005 g to 0.300 g, while the frequency response is from DC to 35 Hz.

The recorders were built by Kinemetrics for a previous earthquake measurement program and have been reconditioned and tested for use here. When they receive a signal from either trigger they activate. Full recording speed is reached in 100 milliseconds. They continue to run for 20 seconds after the last trigger pulse. There are six recorders in the instrument rack, one for each triaxial accelerometer, one for timing and one spare. Each unit records three data signals plus a common timing signal on a data tape cassette. In turn, these data may be played back on a Kinemetrics SMP-2 and then loaded into a computer for analysis. Figure 9 is a sample plot of an unknown event probably caused by offloading of a work boat.

The trigger units used are housed with the deck mounted accelerometers. They are Kinemetrics VS-1 type devices. Both are connected in parallel and set to activate at 0.01 g.

AMBIENT PLATFORM VIBRATION TESTS

This earthquake system has also been used to measure ambient platform motion caused by normal sea states. For these tests an extra amplifier chassis was added to increase the system gain from 4 to 400. The entire unit was then operated in conjunction with a portable monitoring facility known as the Moveable Offshore Dynamic Acceleration Laboratory or MODAL. See Figure 10. It uses similar electronics and handles five sets of triaxial motion sensors which may be moved anywhere on the platform or lowered into the chutes for mudline motion and mode shape determination.

Ambient platform acceleration data were gathered during July, 1983 and will be taken again following a strong earthquake. This would help greatly in determining the post earthquake condition of the structure and will aid in evaluating the degree of underwater inspection required.

CONCLUSIONS

Both phases of the project are successful. In Phase I the SMA-2's have worked satisfactorily for over three years and are still performing normally. The more elaborate system used in Phase II has done a good job since its installation. It has recorded data and its calibration has not appreciably changed during its life. The playback system is adequate and permits use of a computer to analyze the data. Finally, the Phase II system is compatible and adaptable with a mobile unit to gather important ambient vibration data before or after any strong motion event.

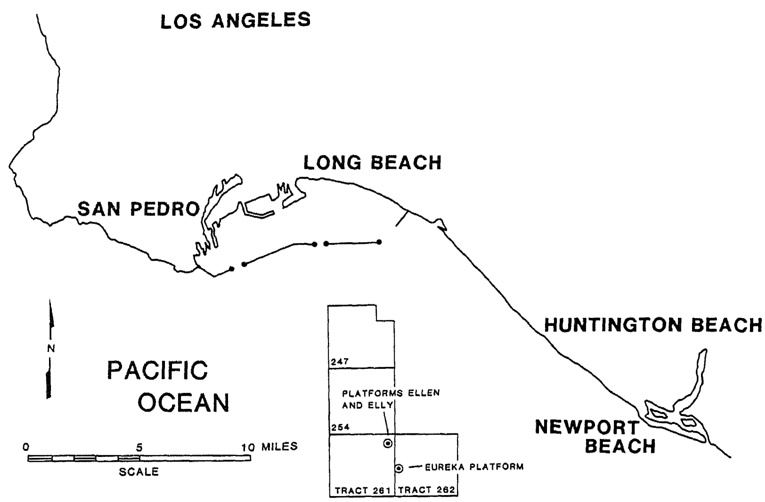

FIGURE 1. BETA FIELD SITE PLAN

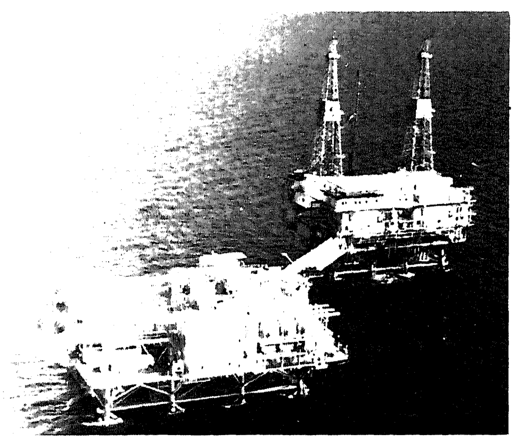

FIGURE 2. PLATFORMS "ELLEN" AND "ELLY"

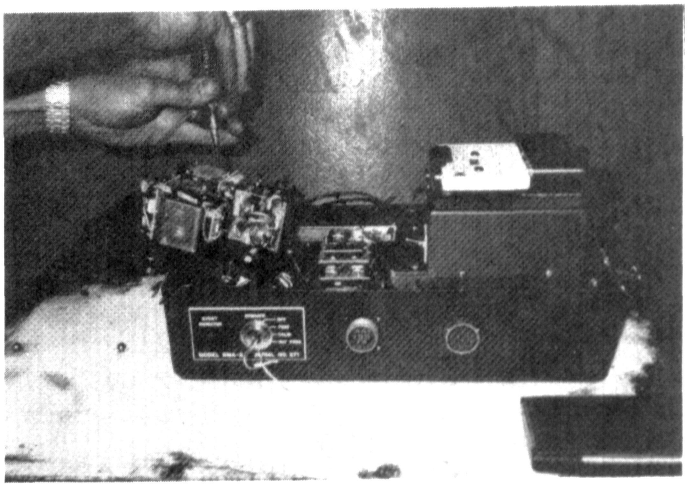

FIGURE 3. KINEMETRICS SMA-2

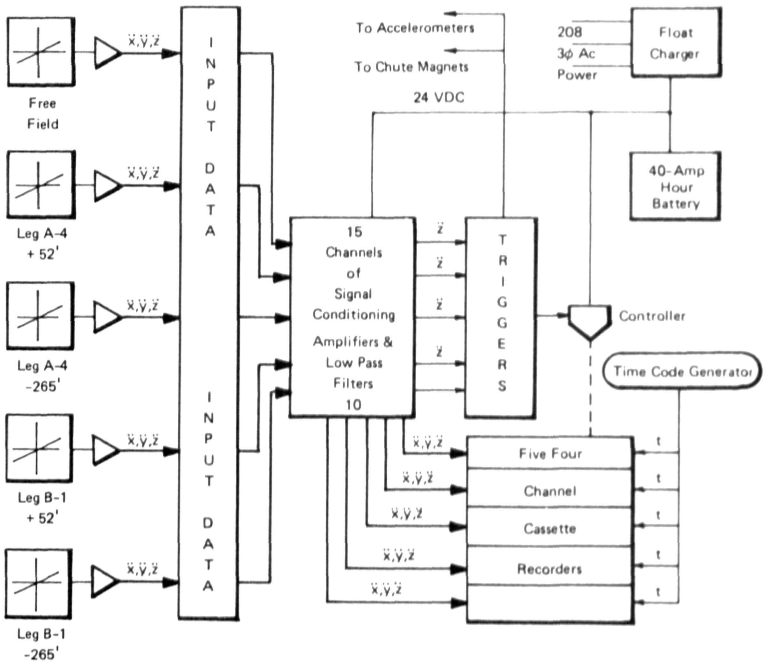

FIGURE 4. BLOCK DIAGRAM OF BETA EARTHQUAKE ACCELERATION MONITORING SYSTEM

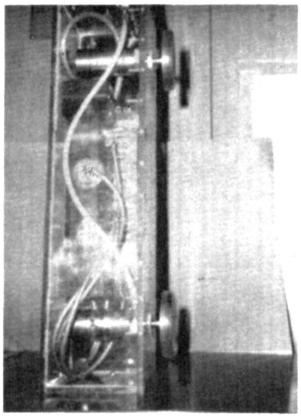

FIGURE 5. LEXAN CHUTE PACKAGE.

FIGURE 6. CHUTE PACKAGE INSTALLATION.

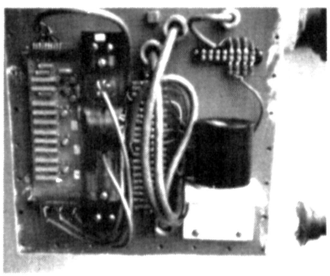

FIGURE 7. DECK MOUNTED PACKAGE WITH TRIGGER.

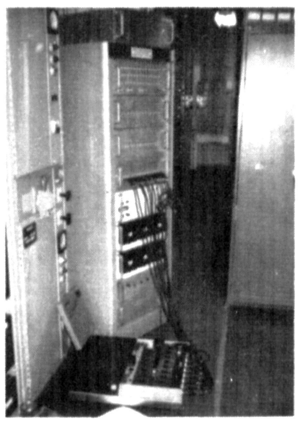

FIGURE 8. BETA EARTHQUAKE ACCELERATION MONITORING SYSTEM RACK.

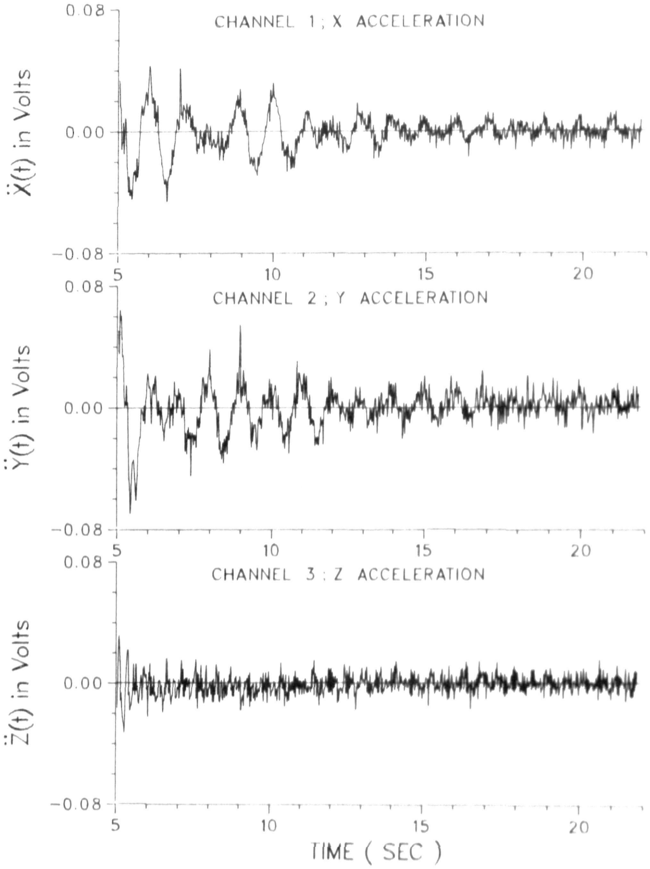

FIGURE 9. SAMPLE PLOT.

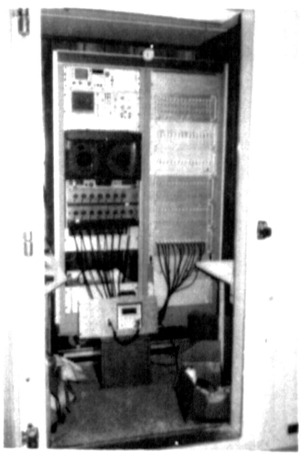

FIGURE 10. MODAL SYSTEM.