ANCO

SEISMIC TESTING OF AN EARTHQUAKE ALARM

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12 November 2003

earthquake/emergency alarm
SOS-LIFE
seconds can save your life...

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1.0 INTRODUCTION

ANCO Engineers. Founded in 1971, has performed seismic shake table testing on over 500 components used in power plants, telecommunication facilities, industrial facilities, and consumer products. ANCO also constructs and installs shake tables and other seismic test systems. Additional information on ANCO can be found at ancoengineers.com.

SOS-Life has produced an alarm that senses the early vibrations caused by an earthquake and triggers an alarm or a relay, which will serve to give users a few seconds warning of the larger vibrations to follow or to shut off critical equipment and utilities, such as gas and electricity. ANCO Engineers was contracted by SOS-LIFE to perform vibration tests on these alarms to determine their satisfactory operation and sensitivity. These tests are typical industrial seismic tests as described herein, and are guided by the discussion presented below. As there are no set standards for such alarms and their performance, these comments represent the best judgment and recommendations of ANCO.

ANCO tested 7 standard (- two-axial -) alarms (brand name SOS-LIFE "House Warning System") (denoted "HWS" A, B, C, D, E, G, and H) and one relay resetting (- three-axial -) alarm (brand name SOS-LIFE "Building Warning System) (denoted "BWS" F). The standard alarms had been set with different sensitivities by SOS-Life. A photograph of the alarms on the table is shown below. The mounting frame was constructed from ¾" (19 mm plywood). A videotape is also available.

ANCO placed the alarms on a uniaxial electrodynamic shake table (capable of, in turn, both vertical and horizontal excitation) and exposed the alarms to two kinds of vibration. The first was a series of actual recorded earthquake time histories provided by SOS-LIFE. These earthquakes were generated on the table with a variety of different peak acceleration levels, until the acceleration level at which each alarm triggered was determined. During these tests the recorded wave shape was maintained. The only change was an amplitude multiplier to vary the overall acceleration level.

The second series of tests involves exposing the alarm to sinusoidal excitation of different frequency and amplitude and determining the level at which the alarms triggered. This was done at 4, 8, and 16 Hz.

One way in which the alarm can be useful is illustrated in Figure 1. In a typical earthquake the early arriving waves are called primary (P), and are of somewhat lower amplitude than the later arriving secondary (S) waves. The further away the earthquake epicenter the longer the lag between the primary and secondary waves. The lower scale in Figure 1 shows, for example, that for an earthquake with epicenter 200 km (120 miles) away, this lag will be about 24 seconds. For an earthquake 30 km (about 20 miles) away, this lag is about 3 seconds.

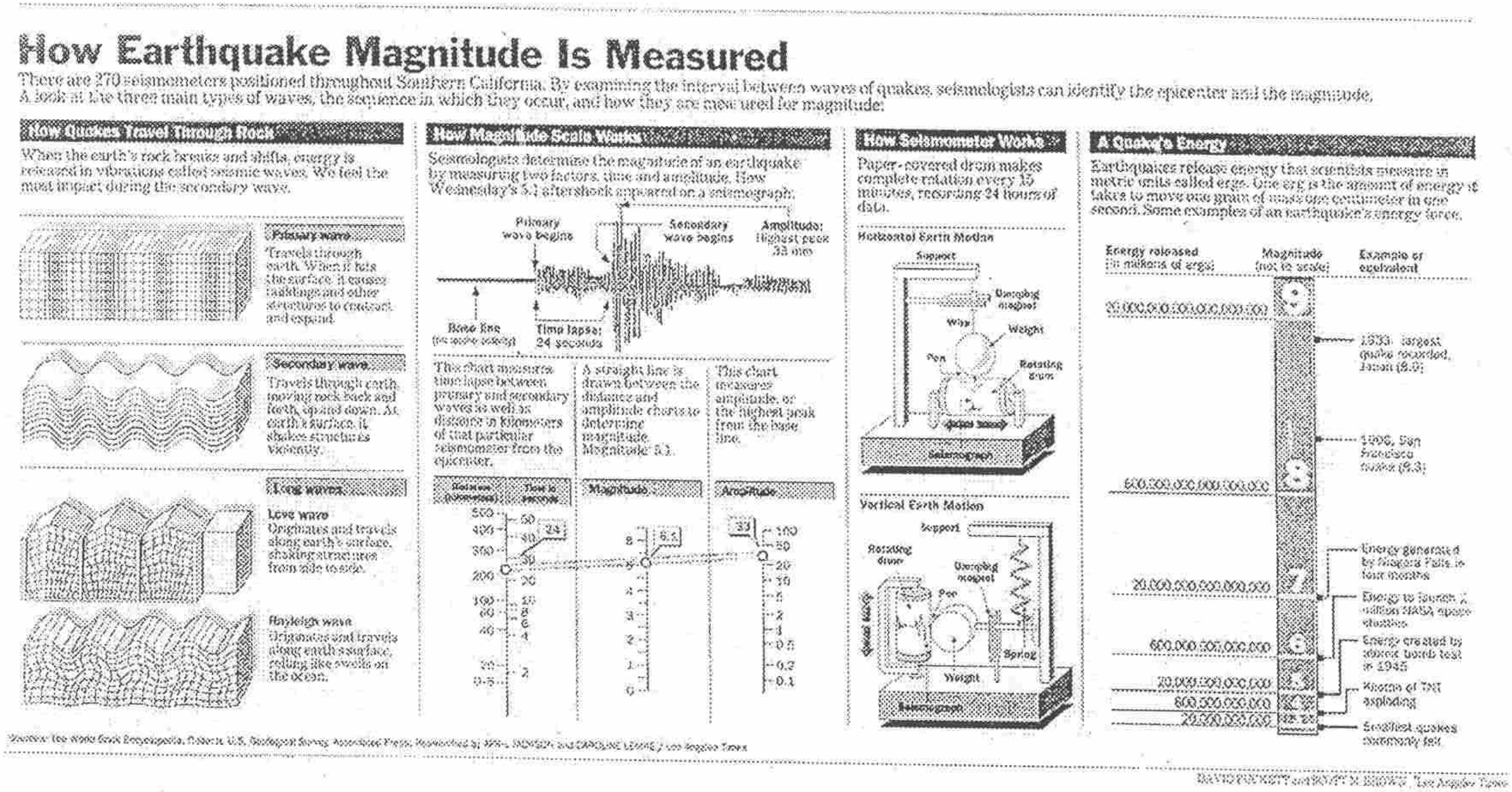

Figure 1. : Waves in a Typical Earthquake

If an earthquake is more than about 200 km away, it is very unlikely to cause significant damage or be of great concern to people. Hence if the alarm can detect the early primary waves it can warn people of the arrival of the significant larger secondary waves by up to 20 seconds or so. There have been a few distant destructive earthquakes during which the early P waves arrived about 60 seconds before the destructive S waves.

If the earthquake is closer, of course, the warning time will be less, conceivably zero seconds if the earthquake is within a few kilometers. However, even with close earthquake the secondary waves take a few seconds to build up (see typical trace in Figure 1). Hence, by detecting the first few cycles of the secondary wave, the alarm can give a few seconds of warning for even close in earthquakes.

Hence the SOS-LIFE alarm could be expected to provide from roughly 2 to 20 seconds of warning in the event of a significant earthquake. Such a warning may be useful for sleeping people, to give time to "duck and cover", find ones glasses or other important items before the potential loss of lighting, begin to gather family members, prepare oneself psychologically, etc. The turning on of a light in the event of an earthquake is useful, as power is often lost in a significant event. Lastly, the relay activation alarm can serve to shut down critical electrical equipment, at a time when people's mind will be confused and directed elsewhere.

An important feature of such an alarm is that it does not trigger needlessly or at the slightest vibration. An alarm would lose its usefulness if it often triggered when someone walked heavily by, or from street traffic, wind, closing of a door, etc. Thus the alarm must be sensitive enough to trigger during the arrival of significant primary waves (typically 1%-10% g), but not during "routine" urban vibration (typically up to 3% g).

2.0 EARTHQUAKE TEST RESULTS

(Note that Unit G was eliminated from the test series for technical reasons.)

2.1 Vertical Trigger Levels

Note: "239 Z", for example, means the Z (vertical) component of earthquake #239

All acceleration values are in "g's" (1 g = 9.82 m/s^2)

Average means the average trigger value in all the earthquakes

">" indicates that the unit triggers at some value above the indicated value which was the maximum value possible for this particular earthquake due to controller limitations on amplification of very small measured earthquakes. (The controller could not amplify an earthquake by more than a factor of 10 above the actual recorded value). This value is not used for the average value.

Unit	239 Z	354 Z	588 Z	87113 Z	Average
HWS A	0.13	0.13	0.10	0.10	0.12
HWS B	0.12	0.10	0.10	0.08	0.10
HWS C	0.11	0.08	0.10	0.08	0.09
HWS D	0.11	0.10	0.08	0.08	0.09
HWS E	0.05	0.04	0.06	0.04	0.05
BWS F	0.12	.0.08	0.08	0.06	0.09
HWS H	0.20	0.16	0.20	(>0.11)	0.19

2.2 Horizontal Trigger Levels

Note: This first table is for horizontal motion perpendicular to the "wall" that the units were attached to. The X component of the measured earthquake was used.

Note that the H 1.20 g trigger of H in earthquake 239 X and D 1.04 g trigger in earthquake 588 X threw the units off their wall mounting bracket

Unit	239 X	354 X	588 X	87113 X	Average
HWS A	0.90	>0.56	1.04	>0.11	0.97
HWS B	0.90	0.39	0.82	>0.11	0.70
HWS C	0.90	>0.56	0.82	>0.11	0.86
HWS D	0.90	>0.56	1.04	>0.11	0.97
HWS E	0.04	>0.56	0.60	>0.11	0.32
BWS F	0.21	0.28	0.07	0.07	0.16
HWS H	1.20	>0.56	1.04	>0.11	1.12

Note: This second table is for horizontal motion parallel to the "wall" that the units were attached to. The Y component of the measured earthquakes was used.

Unit	239 Y	354 Y	588 Y	87113 Y	Average
HWS A	0.14	0.14	0.25	>0.012	0.27
HWS B	0.14	0.14	0.17	>0.012	0.23
HWS C	-	-	-	-	-
HWS D	-	-	-	-	-
HWS E	-	-	-	-	-
BWS F	0.22	0.14	0.17	>0.012	0.18
HWS H	0.22	0.26	0.33	>0.012	-

2.3 Effective Trigger Times in Measured Earthquakes

ANCO defined the following effective trigger times at the actual level of any given measured earthquake:

The effective trigger time is the time in seconds after the start of the earthquake at which the earthquake reaches the average acceleration trigger level fond in Section 2.1 or 2.2.

Note: "NT" means that the unit would not trigger under the actual measured earthquake.

Note that the alarms did not trigger at the actual measured earthquake levels because these earthquakes were, typically, small. Even in the earthquakes that did trigger the alarms, the triggering occurred only well into the earthquake, at the highest acceleration levels. However, when these measured earthquakes were amplified to levels of concern to individuals, the alarms did trigger at the early parts of the earthquakes, typically within 1-3 seconds of the start of the earthquake. This is the type of behavior one would want in an earthquake alarm.

Unit	239 Z 6 sec. long	354 Z 10 sec. long	588 Z 10 sec. long	87113 Z x sec. long
HWS A	Not recorded	NT	3.0	NT
HWS B	Not recorded	NT	3.0	NT
HWS C	Not recorded	NT	3.0	NT
HWS D	Not recorded	NT	3.0	NT
HWS E	Not recorded	NT	2.7	NT
BWS F	Not recorded	NT	3.0	NT
HWS H	Not recorded	NT	NT	NT

Unit	239 X 6 sec. long	354 X 15 sec. long	588 X 15 sec. long	87113 X 15 sec. long
HWS A	NT	NT	NT	NT
HWS B	NT	NT	NT	NT
HWS C	NT	NT	NT	NT
HWS D	NT	NT	NT	NT
HWS E	NT	NT	NT	NT
BWS F	NT	NT	NT	NT
HWS H	NT	NT	NT	NT

Unit	239 Y 5 sec. long	354 Y 10 sec. long	588 Y 10 sec. long	87113 Y 20 sec. long
HWS A	NT	NT	NT	NT
HWS B	NT	NT	NT	NT
HWS C	Not tested	Not tested	Not tested	Not tested
HWS D	Not tested	Not tested	Not tested	Not tested
HWS E	Not tested	Not tested	Not tested	Not tested
BWS F	1.5	NT	NT	NT
HWS H	Not tested	Not tested	Not tested	Not tested

3.0 SINUSOIDAL TEST RESULTS

To obtain some information on the relative sensitivity of the trigger level at different frequencies, certain units were subjected to vertical sinusoidal vibration at 4, 8, and 16 Hz in turn. The amplitude was varied until triggering occurred. The following are these trigger levels (in g's):

Unit	4 Hz.	8 Hz.	16 Hz.
HWS A	0.08	0.08	0.12
HWS B	0.06	0.08	0.12
BWS F	0.04	0.13	0.09
HWS H	0.12	0.13	0.17

4.0 CONCLUSIONS

- The SOS-LIFE units tested performed in a manner consistent with their intended use as earthquake alarms or earthquake early warning systems. The units are capable of differentiating between "normal" vibrations and small and large earthquakes.

- Triggering during vertical excitation was fairly consistent from earthquake to earthquake and averaged from 0.05 to 0.19 g depending on which unit. Hence these units can be set to an acceleration appropriate to the task (approximately 0.1 g).

- Triggering during horizontal excitation perpendicular to the wall was slightly less consistent and averaged 0.15 – 1.10 g. Hence the units are less sensitive in this horizontal direction than in the vertical direction.

- Triggering in the horizontal direction parallel to the wall was fairly consistent and averaged 0.18 - .27 g, somewhat less sensitive than the vertical direction, but more sensitive than the perpendicular horizontal direction.

- A perpendicular acceleration above approximately 1.1 g can cause the units to fall off of their mounting bracket.

- The triaxial relay unit "Building Warning System" (F) has sensitivities of 0.09 (V), 0.16 (H-Perpendicular), and 0.18 g (H- Parallel).

- Most of the recorded earthquakes were fairly low level (under 0.10 g) and consequently most of the units did not trigger when exposed to the actual level of the measured earthquakes. This is consistent with the correct operation of the units.

- For the sinusoidal frequencies tested there was not great variation in sensitivity, the units averaging a trigger level of about 0.10 g. There is some reduced sensitivity at the higher frequency (16 Hz) than at the lower frequencies (4 and 8 Hz). Reduced sensitivity at the higher frequency is actually desirable, as the unit will be less susceptible to undesired triggering during normal urban vibrations.

- Note that these tests were performed on a uniaxial table. Each of the three axes of earthquake motion was applied, but sequentially instead of simultaneously. If, as is the case in actual earthquakes, all three axes were applied simultaneously then most likely the trigger levels measured would be slightly lower. That is, in an actual earthquake the alarms would probably be slightly more sensitive and trigger at slightly lower accelerations than measured in these uniaxial tests.