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# SEISMIC TESTING OF AN EARTHQUAKE RESISTANT WINE RACK SYSTEM CALLED "Quake Guardian"

Prepared for:

Sterling Products
1214 Cambridge Street
Novato, CA 94947
(415) 883-6396

Approval Signatures:

_____
Project Manager/Date

_____ _____
Technical QA/Date Editorial QA/Date

_____
Chief Engineer/Date

Prepared by

***ANCO Engineers, Inc.***

1965-A 33-rd Street
Boulder, Colorado, 80301 USA

(303) 443-7580
anco@ancoengineers.com
ancoengineers.com

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## 1.0 INTRODUCTION AND SUMMARY

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.

STERLING PRODUCTS has produced an earthquake resistant system on a wine rack called “Quake Guardian” that uses a hoop and coiled spring to hold the wine bottles in the rack during an earthquake. ANCO Engineers was contracted by STERLING PRODUCTS to perform side by side vibration tests on the Quake Guardian and a conventional wine rack to determine their relative ability to protect the wine bottles during different sizes of earthquakes. 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 wine racks, these comments represent the best judgment and recommendations of ANCO.

In April 2005 and August 2005 ANCO tested two 30-bottle wine racks (see Figure 1). In tests 1-3 the rack to the left was a standard wine rack with an approximately 7 degree slope to the rack rails. The rack to the right was the STERLING PRODUCTS Quake Guardian wine rack with horizontal wine rails and coil/hoops to hold each bottle. In tests 5-7 the location of the racks were reversed (right to left). The racks were filled with standard wine bottles filled with water and corked by a professional winery. A few bottles contained actual wine. The mounting frame was constructed from ½” drywall attached to an Oak pallet attached to the shake table with a steel angle frame. Each wine rack was attached to the frame using six 10-32 steel bolts through the drywall and through the wood frame. A videotape of the tests was made and is presented separately.

The tests performed in April used Quake Guardian hoops with 5/32” crimps. The tests in August used Quake Guardian hoops with 5/16” crimps, to provide improved holding power.

The results of these tests clearly showed that the Quake Guardian was able to protect the wine bottles from falling out at much larger earthquakes than the conventional wine rack. The Quake Guardian protected the bottles from several earthquakes of increasing size. It was clear that the conventional wine rack could spill out bottles during moderate earthquake events.

ANCO's observations also suggest the following:

- When mounting any wine rack to a wall make sure to use strong anchors or lag screws into the wood studs. The use of small plastic anchors or Molly type bolts into drywall only may not provide sufficient strength to keep the wine rack on the wall during a strong earthquake. Keeping the wine bottles in the rack is a very important requirement. But one must also keep the wine rack on the wall.

- ANCO also recommends that a sheet of drywall, plywood, or similar "soft" material be placed between the wine rack and the wall, if the wall is brick, concrete, or masonry. Earthquake induced motion of the wine bottles in the rack, even if they do not fall out, cause the bottles to knock against the back wall and could cause bottle breakage.

- ANCO also recommends that after an earthquake that both the wine rack anchorage and the "hoop and coils" of the Quake Guardian be inspected for possible loosening or damage, and replaced as needed. After a large earthquake it may be prudent to automatically replace all the hoops and coils.

At ANCO, the following people participated in the wine rack tests: Mike Dillard, Paul Ibanez, Cody Weller, and Doug Weller. At STERLING PRODUCTS Mr. Edmund Schmidt was involved.

Figure 1:  WINE RACK TESTSETUP

ANCO placed the wine racks and attachment fixture on ANCO's R-1 vector biaxial shake table. This servo-hydraulic actuated table produces a coherent vector earthquake motion with the vertical component equal to 2/3 of the horizontal motion, which is similar to most earthquakes. The table was controlled using a Data Physics Vector PC based digital controller which allowed adjusting the amplitude of the earthquakes while maintaining the wave form at approximately the same shape. The motion of the table was monitored using a Piezoelectric Dytran horizontal table accelerometer.

The wine racks were exposed to typical broad band earthquakes. The time histories and "response spectra" are shown in Figure A1-A6???? in Appendix A. Note that a response spectrum is used by earthquake engineers as a way to describe an earthquake and at what frequencies it contains energy. For most purposes the time history and response spectrum contain the same information, and are just different ways of looking at the same thing – the earthquake and the nature of its motion.

Most people think of earthquake size as measured by the Richter Scale (Richter Magnitude). Most people realize that a Richter Magnitude earthquake of 3 is fairly small, barely noticeable, of 5 begins to be serious and can do damage, a 6 or 7 is major, an 8 or 9 occurs only a few times a century and is catastrophic if near inhabited areas.

However, some people misuse or misunderstand Richter Magnitude. To use it effectively to relate to earthquake time history amplitude or response spectrum one must specify how far away one is from the earthquake epicenter, the location of the fault line, duration of the earthquake, the type of soil or rock one is on, the type of building one is in, etc. These relationships are complex and approximate.

Speaking in a broad brush, for the type of 30 second long earthquake used for these tests, assuming one is near the epicenter and not in the upper floors of a tall building, then the following approximate correlations can be used: Note that 1.0 G is the acceleration of earth's gravity (32.2 ft/sec$^2$ or 9.8 m/sec$^2$).

| Richter Magnitude | Peak Horizontal Ground Acceleration in G's |
|---|---|
| 8 | ~1.5 |
| 7 | ~1.2 |
| 6 | ~0.8 |
| 5 | ~0.4 |
| 4 | ~0.3 |
| **3** | ~0.2 |

This report uses these approximate relationships to estimate the Richter Magnitude of the earthquakes to which the wine racks were tested.

## 2.0 EARTHQUAKE TEST RESULTS

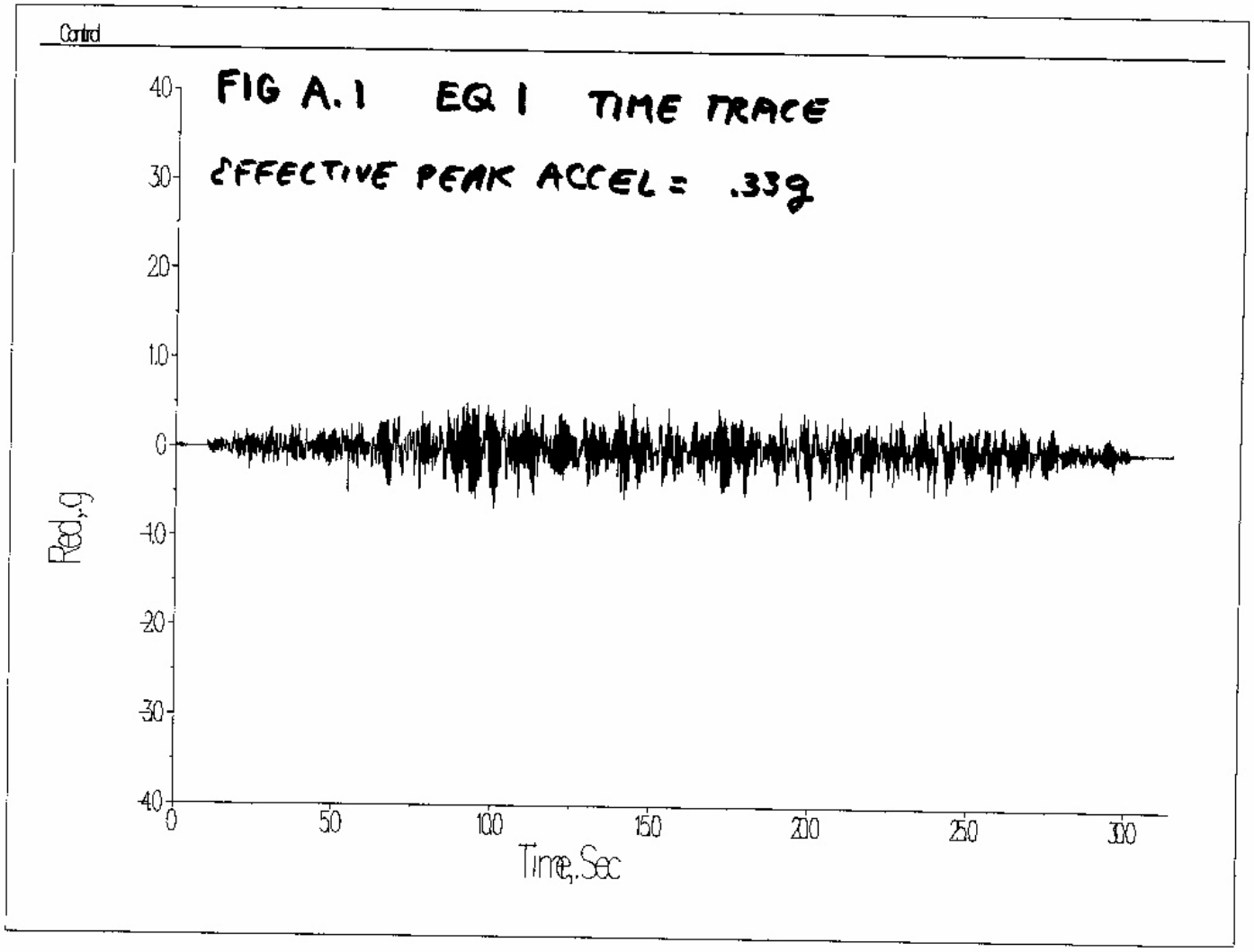
ANCO ran 6 documented earthquakes to test the wine racks. (Several undocumented earthquakes were run to set up the test.) They had the following approximate effective peak accelerations and Richter Magnitudes:

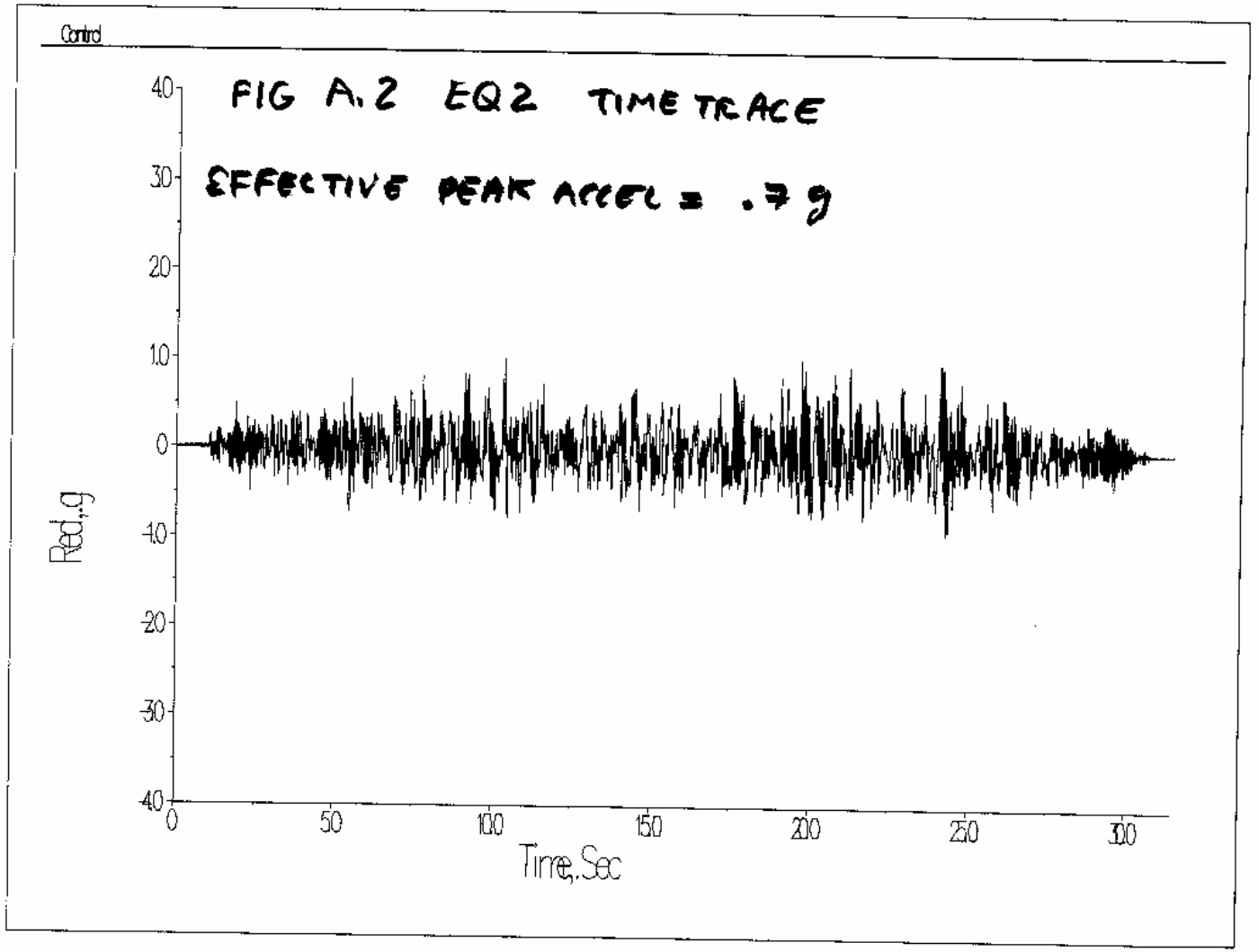
| Test Number (crimp size) | Effective Peak Horizontal Acceleration in G's | Approximate equivalent Richter Magnitude | Test Result |
|---|---|---|---|
| 1 (5/32") | ~0.33 | 4.0 – 5.0 | No bottles in either wine rack fell out |
| 2 (5/32") | ~0.7 | 5.0 – 6.0 | No bottles in either wine rack fell out, but the bottles in the conventional wine racks appeared very close to falling out |
| 3 (5/32") | ~1.0 | 6.0 – 7.0 | All 30 bottles in the conventional wine rack fell out.<br><br>5 of the 30 bottles in the Quake Guardian wine rack fell out (broke the hoop/coil) |
| 4 (not recorded) | --- | --- | --- |
| 5 (5/16") | ~0.7 | 5.0 – 6.0 | No bottles in either wine rack fell out, but the bottles in the conventional wine racks appeared very close to falling out. |
| 6 (5/16") | ~1.0 | 6.0 – 7.0 | All of 30 bottles in the conventional wine rack fell out. |

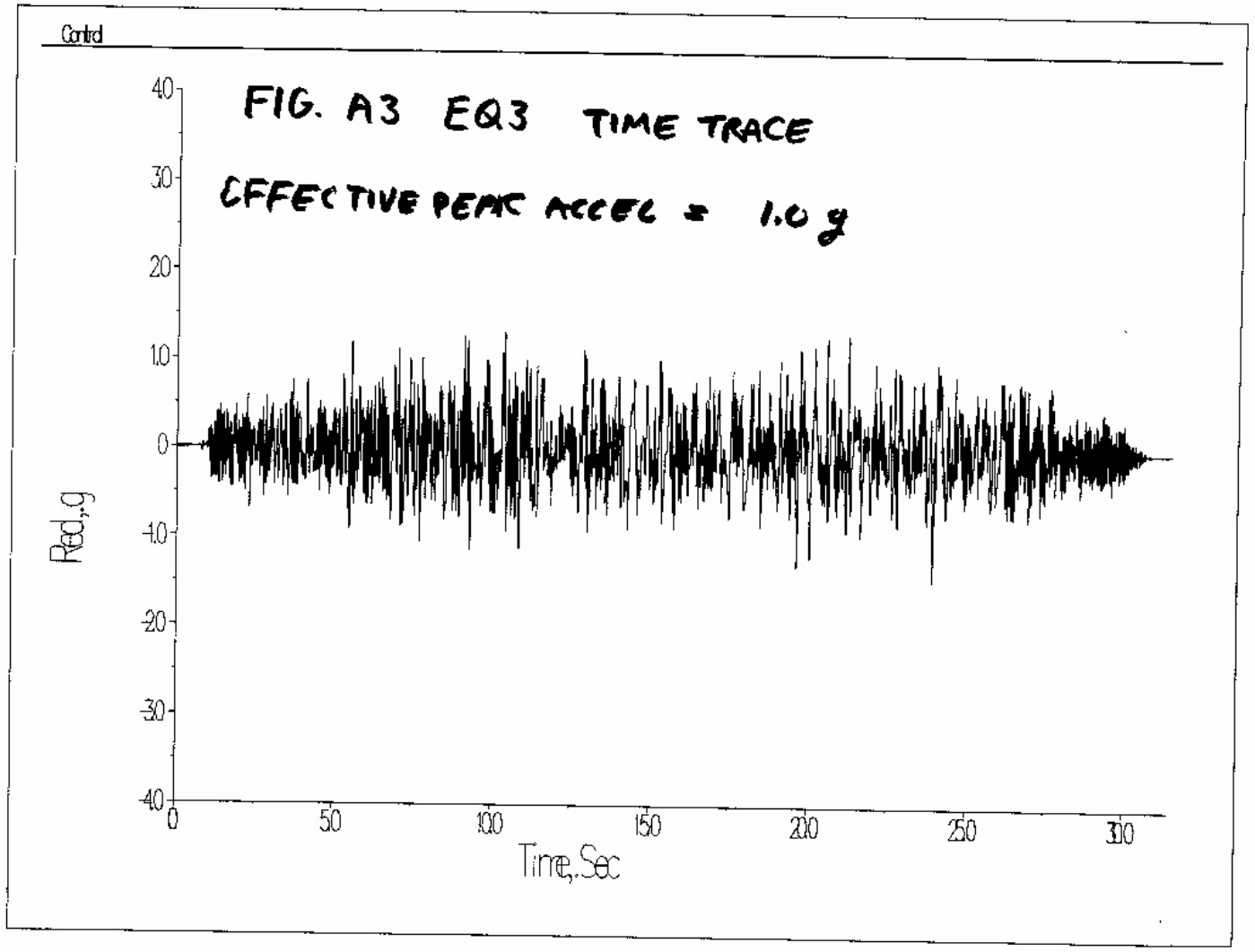
| | | | |
|---|---|---|---|
| 6 (5/16”) Cont from other page | ~1.0 | 6.0 – 7.0 | 1 of the 30 bottles in the Quake Guardian wine rack fell out (broke the hoop/coil) |
| 7 (5/16”) | ~1.3 | 7.0 – 8.0 | 2 more of the 29 remaining bottles in the Quake Guardian wine rack fell out (broke the hoop/coil) |

# Appendix A

# DATA SHEETS


Control
FIG A.1 EQ 1 TIME TRACE
EFFECTIVE PEAK ACCEL = .33g
40
30
20
1.0
0
-10
-20
-30
-40
Resl,g
0
50
100
150
200
250
300
Time,Sec


Control
FIG A.2 EQ2 TIME TRACE
EFFECTIVE PEAK ACCEL = .7 g
40
30
20
10
0
-10
-20
-30
-40
Rel.,g
0
50
100
150
200
250
300
Time,Sec


Contrd
FIG. A3 EQ3 TIME TRACE
EFFECTIVE PEAK ACCEL = 1.0 g
40
30
20
10
0
-10
-20
-30
-40
Resl,g
0
50
100
150
200
250
300
Time,.Sec

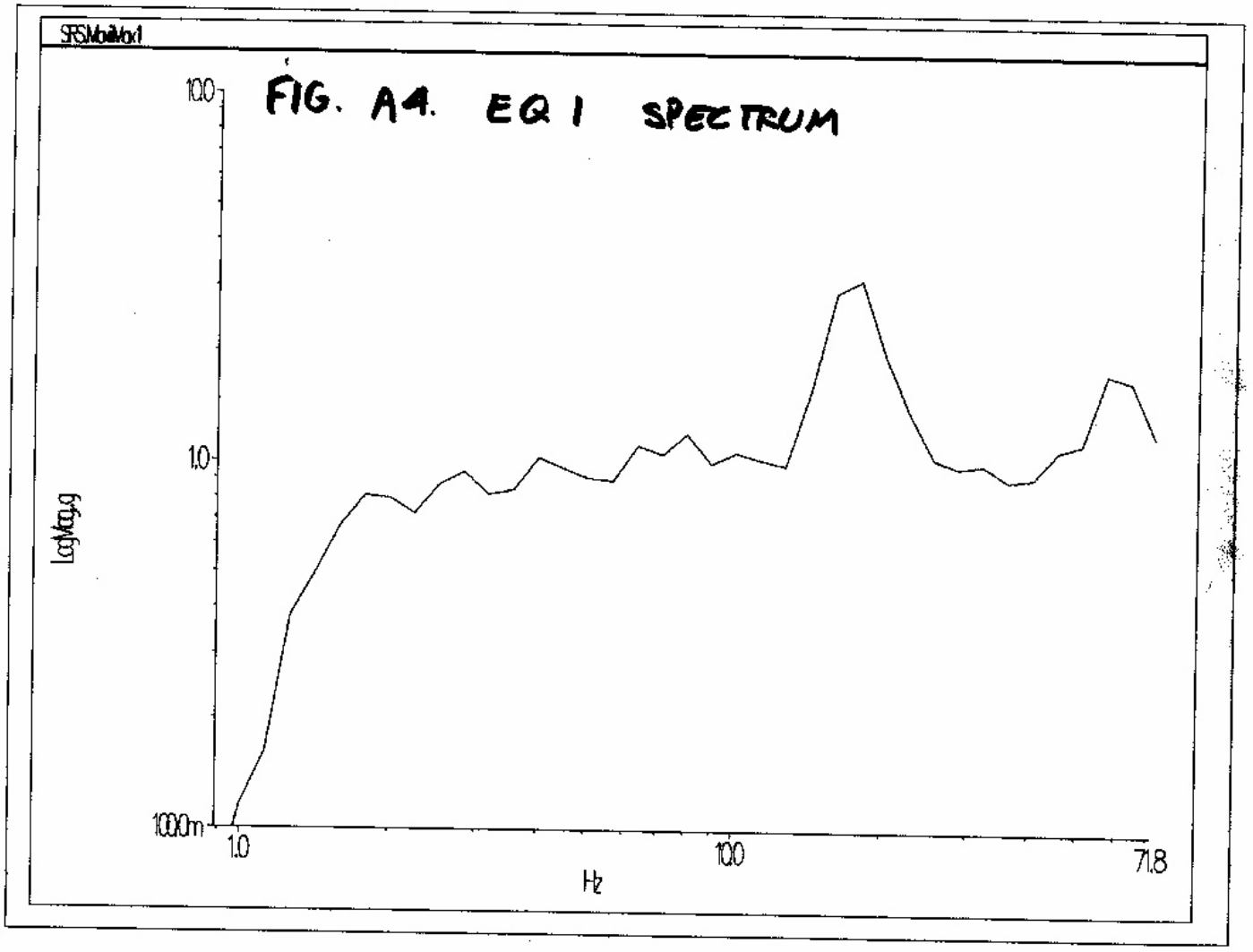
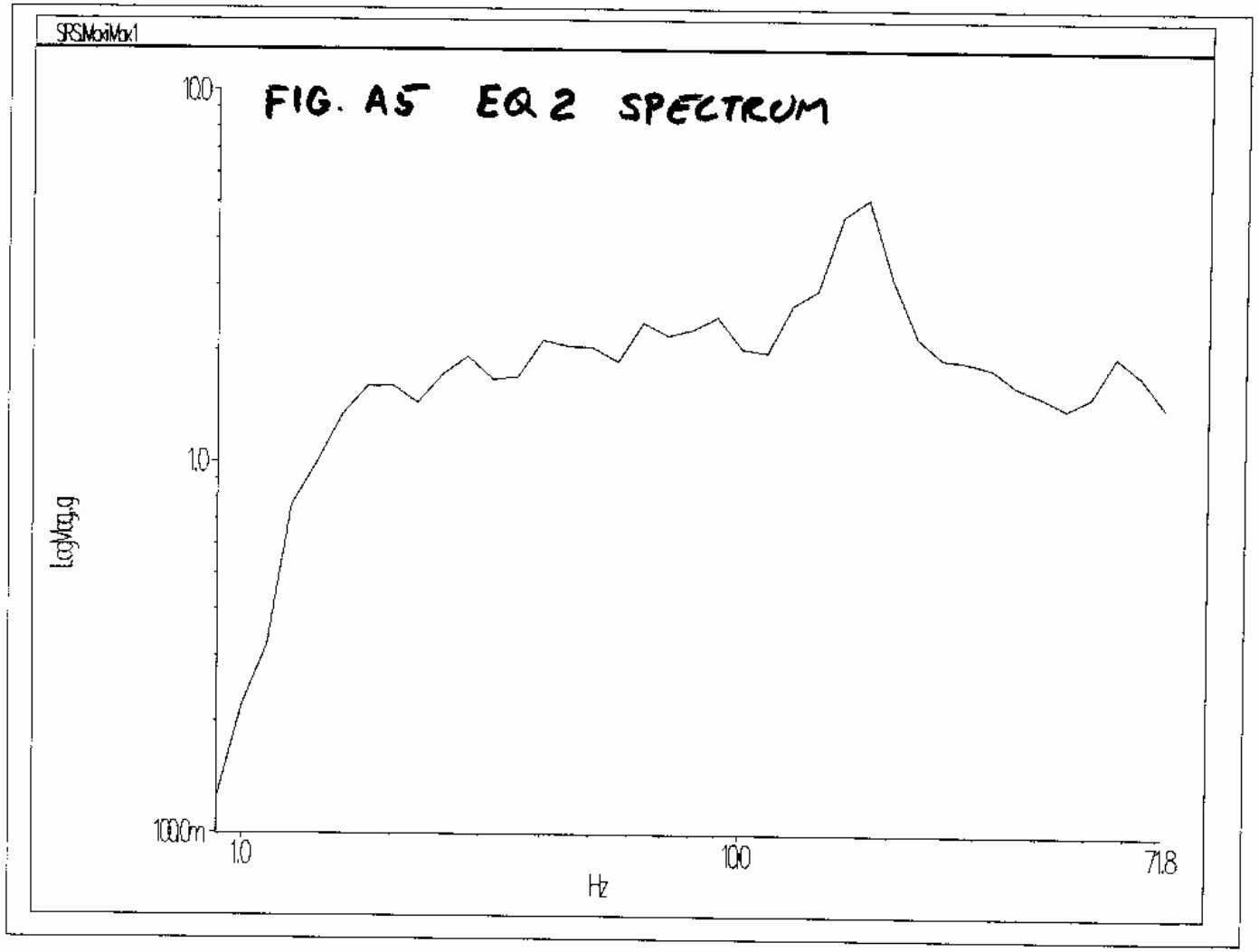



FIG. A4. EQ 1 SPECTRUM


SRSModalMax1
FIG. A5 EQ 2 SPECTRUM
10.0
1.0
100.0m
Log(Mag,g
1.0
10.0
71.8
Hz

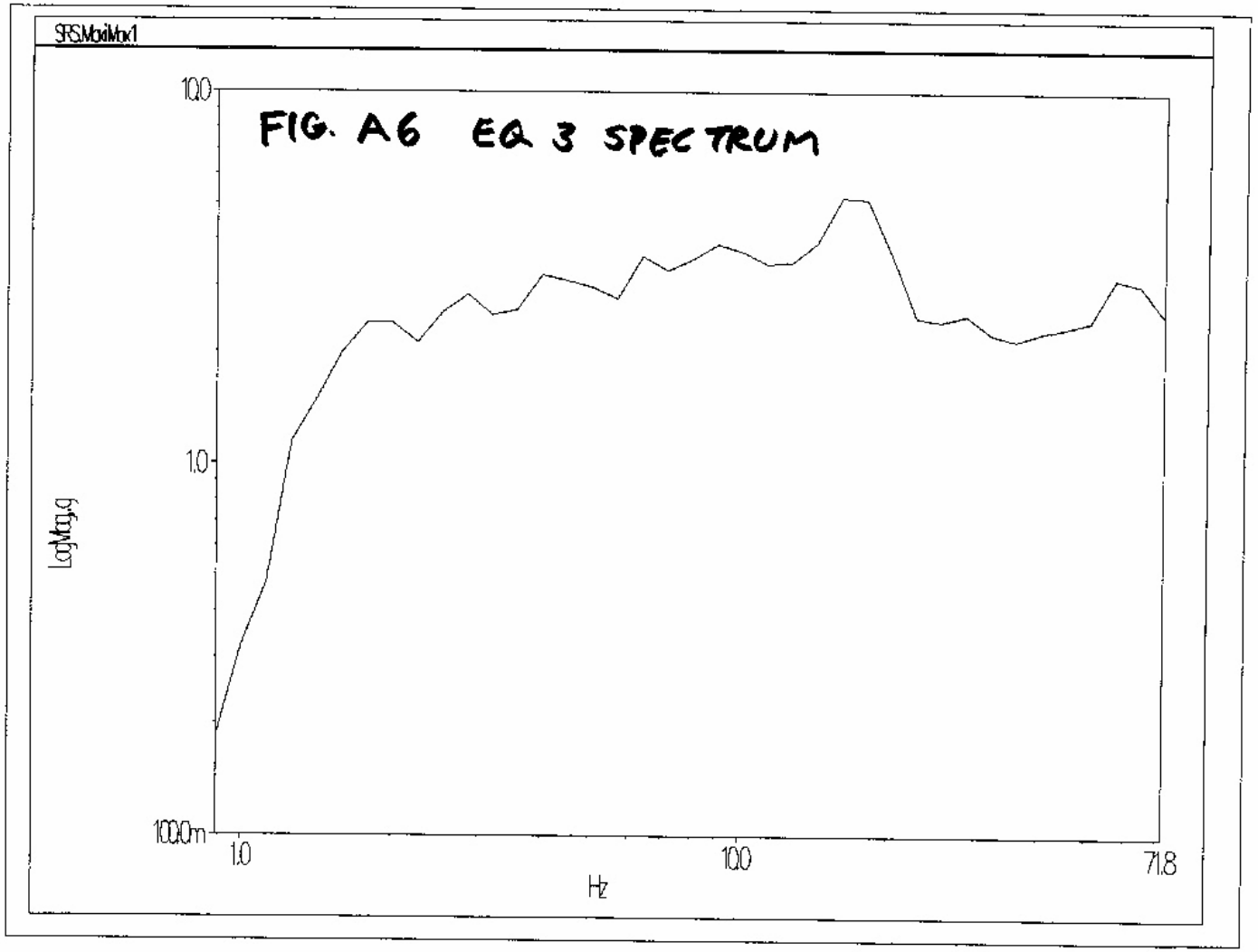



FIG. A6 EQ 3 SPECTRUM

Reference

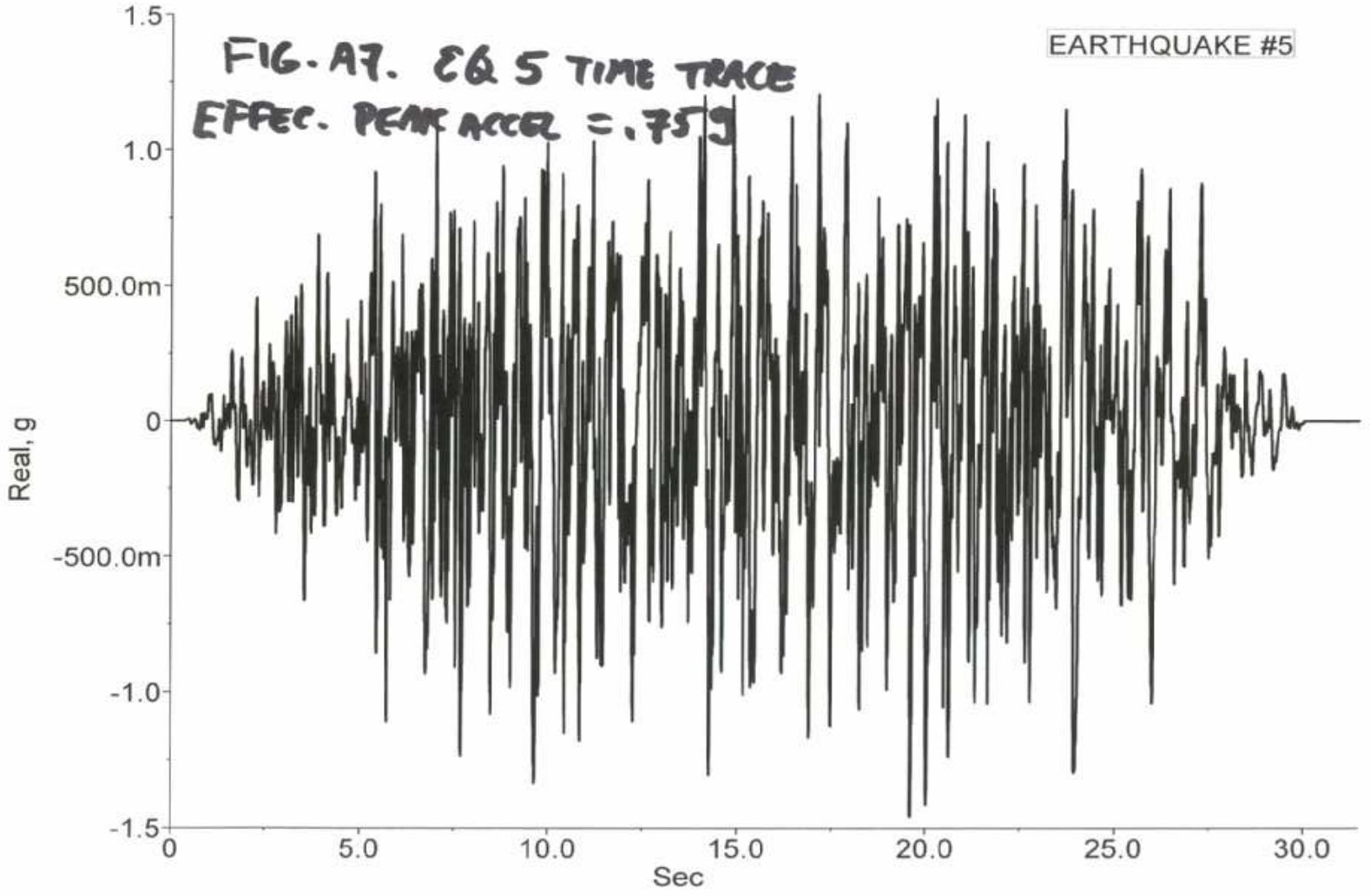
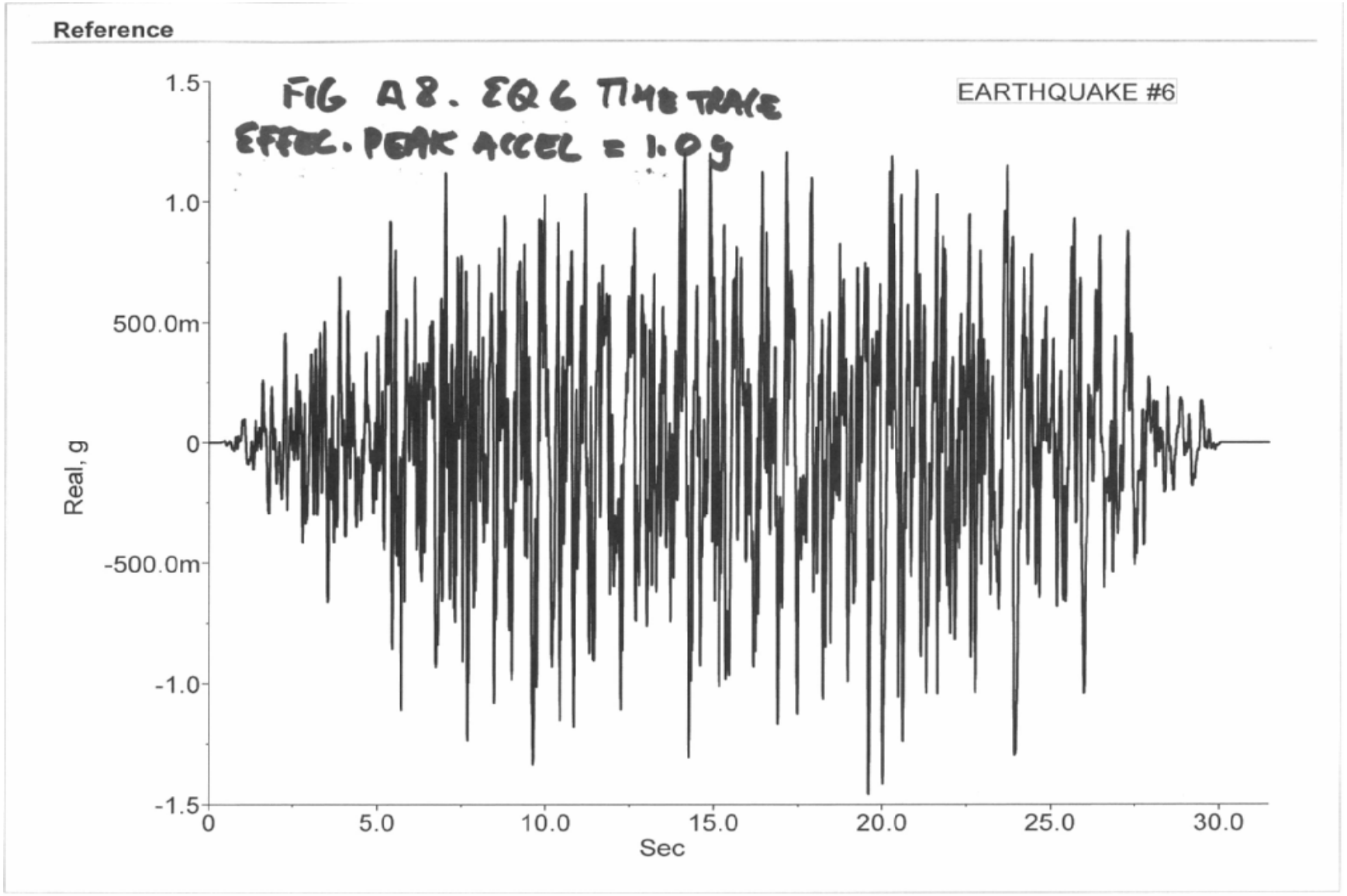


FIG. A7. EQ 5 TIME TRACE
EFFEC. PEAK ACCEL = .75g
EARTHQUAKE #5
1.5
1.0
500.0m
0
-500.0m
-1.0
-1.5
Real, g
0
5.0
10.0
15.0
20.0
25.0
30.0
Sec


Reference
FIG A8. EQ 6 TIME TRACE
EFFEC. PEAK ACCEL = 1.0 g
EARTHQUAKE #6
1.5
1.0
500.0m
0
-500.0m
-1.0
-1.5
Real, g
0
5.0
10.0
15.0
20.0
25.0
30.0
Sec

Reference

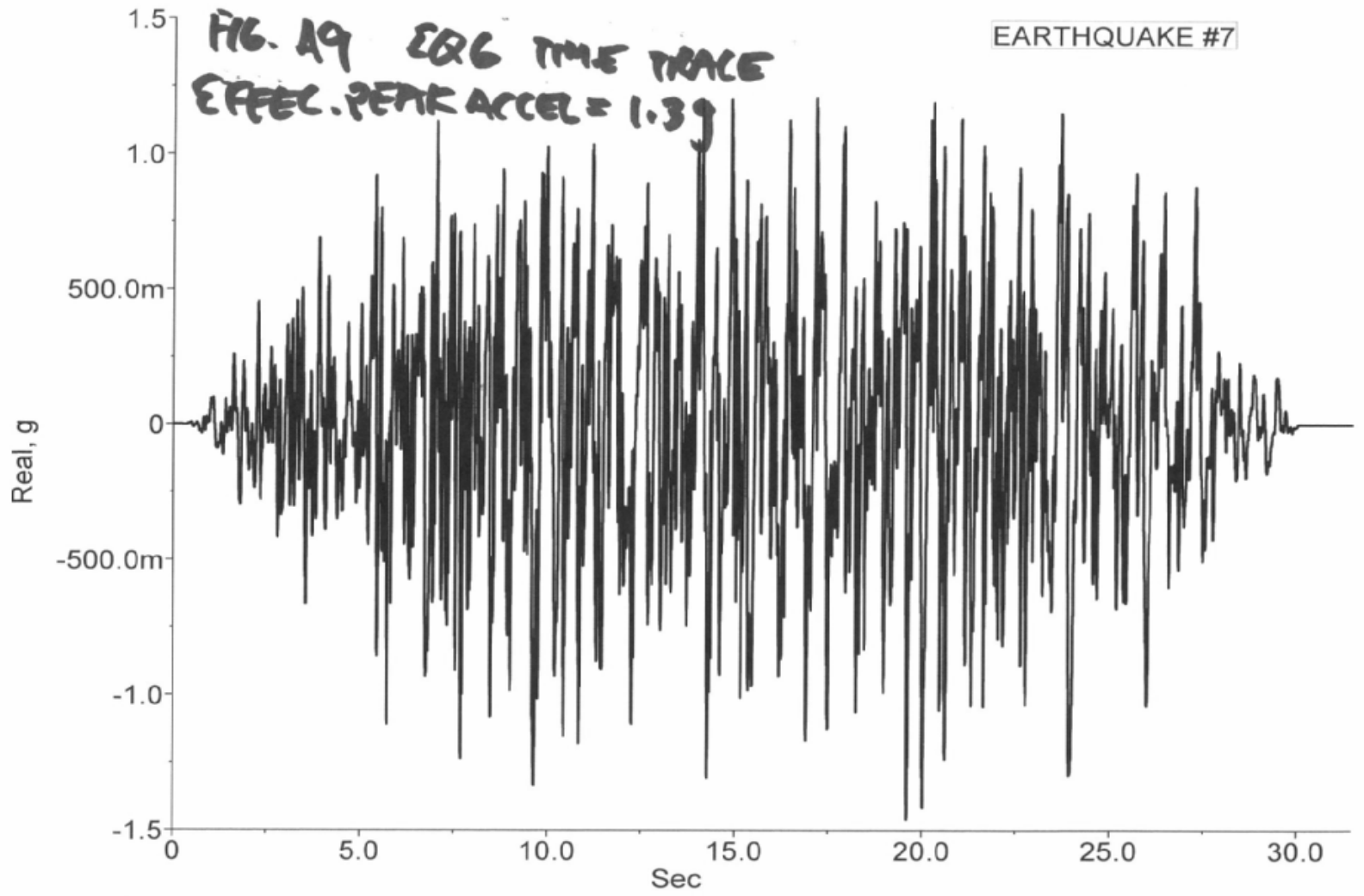
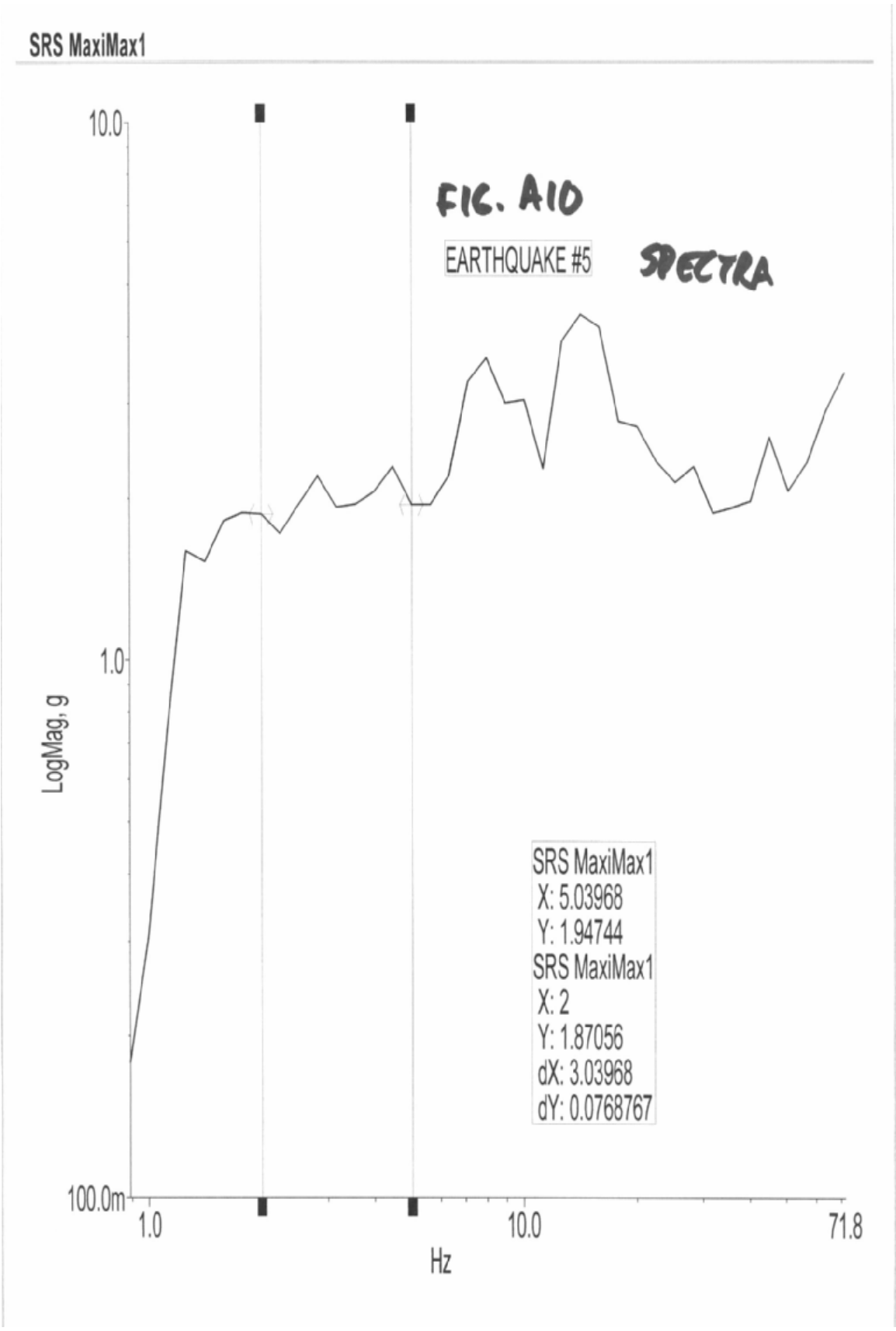
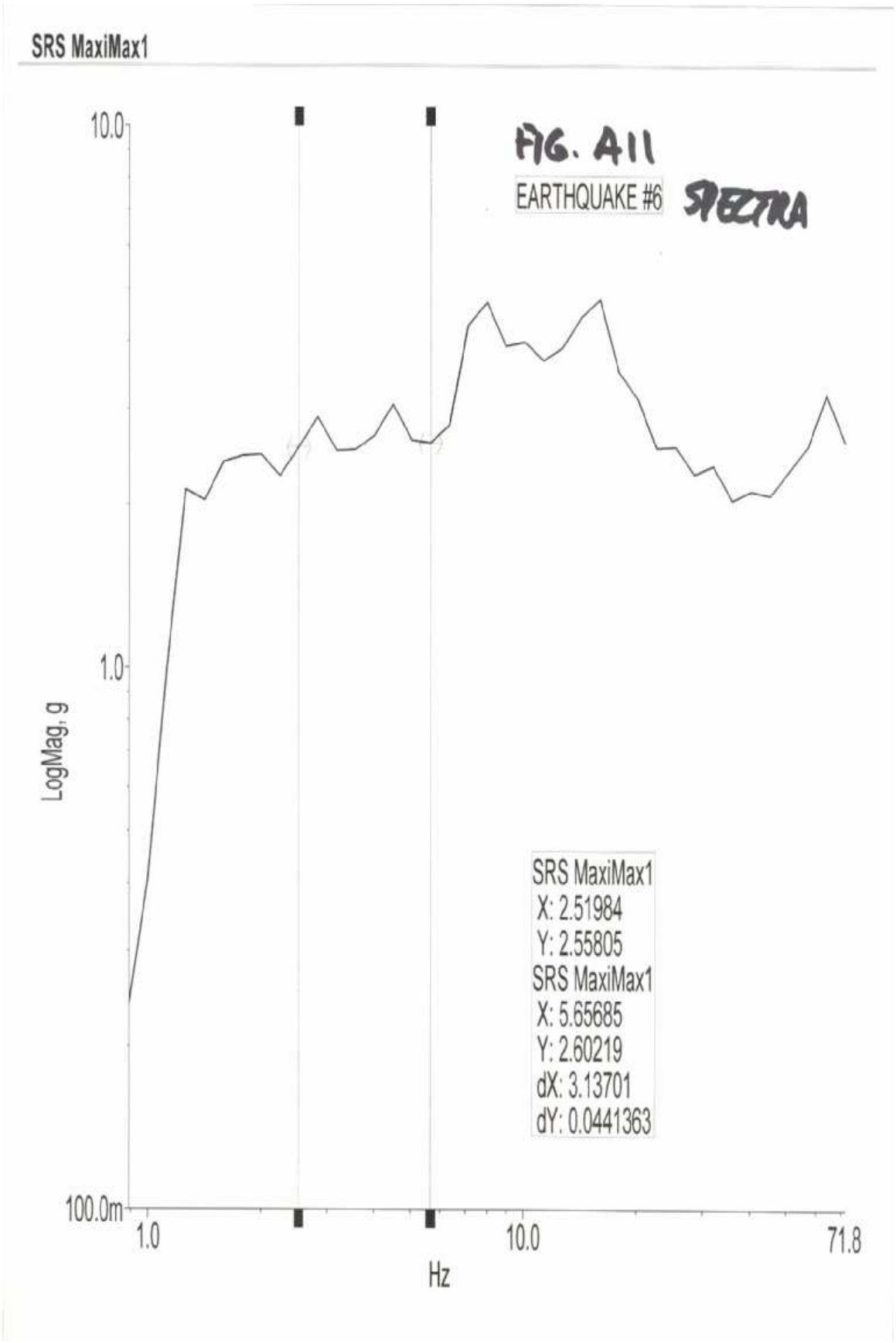
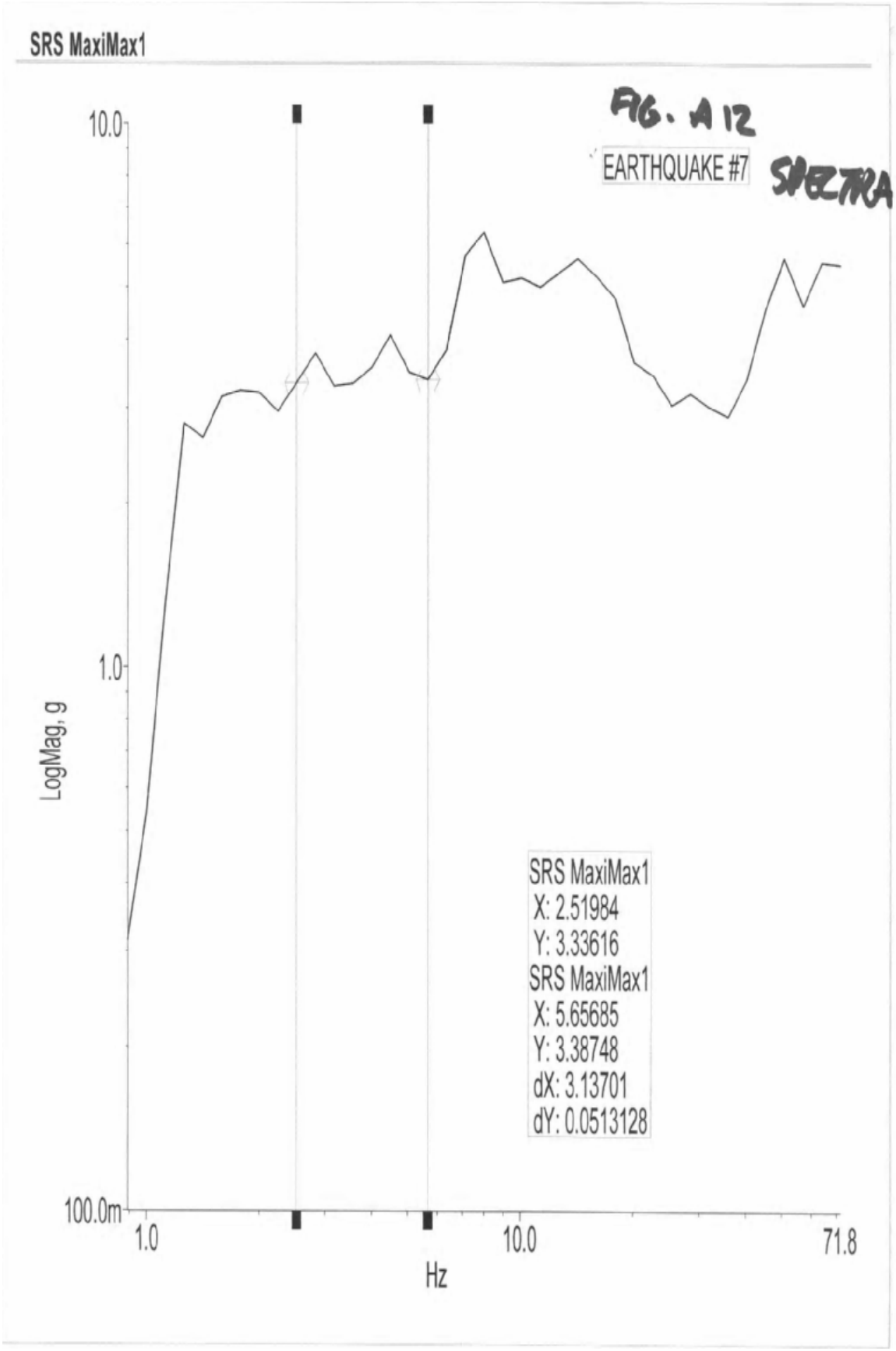


FIG. A9 EQG TIME TRACE
EFFEC. PEAK ACCEL = 1.3g
EARTHQUAKE #7
1.5
1.0
500.0m
0
-500.0m
-1.0
-1.5
Real, g
0
5.0
10.0
15.0
20.0
25.0
30.0
Sec


SRS MaxiMax1
10.0
1.0
100.0m
LogMag, g
FIG. A10
EARTHQUAKE #5
SPECTRA
SRS MaxiMax1
X: 5.03968
Y: 1.94744
SRS MaxiMax1
X: 2
Y: 1.87056
dX: 3.03968
dY: 0.0768767
1.0
10.0
71.8
Hz


SRS MaxiMax1
FIG. A11
EARTHQUAKE #6 SPECTRA
10.0
1.0
100.0m
LogMag, g
SRS MaxiMax1
X: 2.51984
Y: 2.55805
SRS MaxiMax1
X: 5.65685
Y: 2.60219
dX: 3.13701
dY: 0.0441363
1.0
10.0
71.8
Hz


SRS MaxiMax1
FIG. A 12
EARTHQUAKE #7
SPECTRA
10.0
1.0
100.0m
LogMag, g
SRS MaxiMax1
X: 2.51984
Y: 3.33616
SRS MaxiMax1
X: 5.65685
Y: 3.38748
dX: 3.13701
dY: 0.0513128
1.0
10.0
71.8
Hz