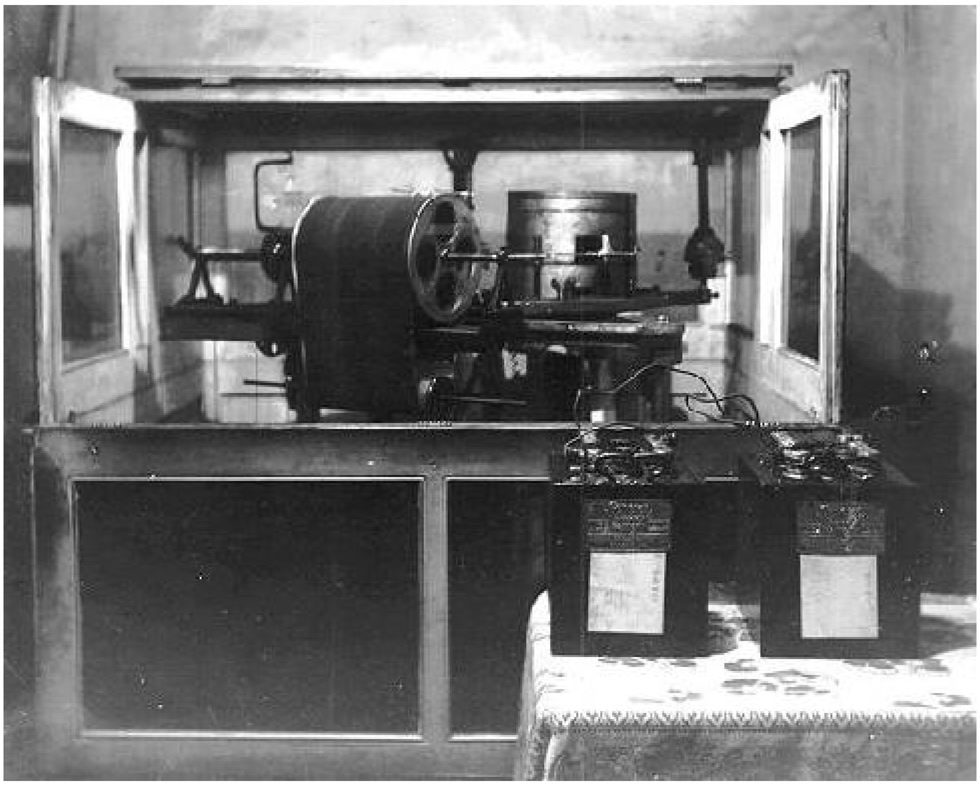
Station Saint Louis, Missouri

Location 38° 38’ 37.0” N

90° 13’ 48.5” W

Instrument: Wiechert 80 kg, Astatic Horizontal Pendulum



The Wiechert 80 Kg. Horizontal Component Seismograph. Located in the basement of DuBourg Hall at Saint Louis University, the seismograph was installed in 1909 and recorded it's first earthquake on October 9th of that year.
(J. B. Macelwane Archives, Saint Louis University)

As a result of an increasing interest in earthquakes, sixteen Jesuit colleges, among them Saint Louis University, were equipped with Wiechert 80 kg astatic horizontal seismographs. The sixteen instruments were located in Georgetown, D.C.; Brooklyn, N.Y.; Fordham, N.Y.; Worchester, Mass.; Buffalo, N.Y.; Cleveland, Ohio; Mobile, Ala.; New Orleans, La.; Chicago, Ill.; Milwaukee, Wis.; St. Mary’s, Kan.; Denver, Colo.; Santa Clara, Cal.; Spokane, Wash.; St. Louis, Mo.; and St. Boniface, Manitoba.

At Saint Louis University, the Wiechert was installed on October 22, 1909. The instrument rested on a concrete pier 4 ft. x 4 ft. x 5.8 ft., constructed to be independent of the building foundation. The pier stood on a few feet of loess underlain by Carboniferous, Silurian Ordovician limestones, shales and sandstones, dipping toward the northeast.

The Wiechert horizontal instrument consists essentially of a heavy mass poised on a vertical stiff rod whose lower end terminates in a Cardanic hinge, which allows the mass to move in any horizontal direction. The mass will not stand in the unstable vertical position without some means of support. It must be attached to the frame, without being so bound to it that it may not remain stationary when the frame oscillates. This is effected by two thrust rods, which meet in the center of oscillation of the mass at an angle of 90° and thence extend, each to the short arm of a lever, whose fulcrum is rigidly fixed to the frame, and whose long arm works against a spring. The pressure of two springs opposes the pull of gravity acting on the mass, which is slightly displaced from the vertical position. The lever is connected at two other points to the recording apparatus and the dampers. Thus changing the distance between the fulcrum spring and thrust rod changes the restoring force which controls the period, and changing the distance between the fulcrum spring and the recorder connection and damper affects the lever magnification and damping forces.

The pens are delicately balanced so that the pressure on the smoked paper is about 1 milligram. The paper is carried on a revolving drum at a uniform rate of 10 cm per minute. Hour and minute marks are placed on the record. Because of the design, the two horizontal components of ground motion can be obtained from the motion of a single pendulum. Also, the periods, static magnification and damping of each component can be different for each component.

Determination of Constants

If a rotational system is subjected to an external acceleration of the frame, the equation of motion can be written as

$$\ddot{z} + 2\zeta\omega_n \dot{z} + \omega_n^2 z = -\ddot{x} \qquad (1)$$

where z is the relative displacement of the center of oscillation. ($z = l\theta$, where the reduced pendulum length $l = K / Mr$, K is the moment of inertia, M is the mass, and r is the distance of the center of mass from the pivot and θ is the angular deflection). If V is the static magnification, level magnification for the Wiechert, the recorded motion $y(t) \equiv Y \exp(i\omega t)$ is related to the ground displacement $x(t) = X \exp(i\omega t)$ by

$$Y = \frac{V\omega^2 X}{(\omega_n^2 - \omega^2) + 2i\zeta\omega\omega_n} \qquad (2)$$

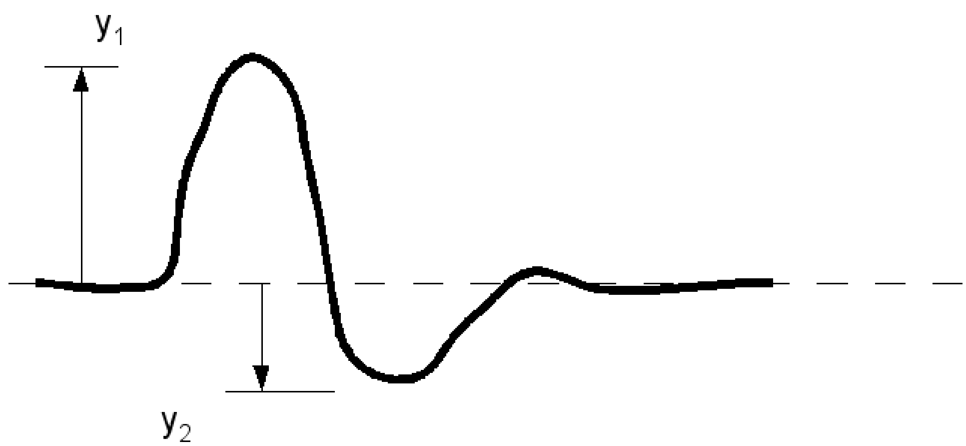
Because of the direct method of recording, both viscous and frictional (coulomb) damping are present. For free vibration in the presence of only viscous damping, the ratio of positive and negative amplitudes over a half cycle is just

$$\begin{aligned} \varepsilon &= \frac{y_1}{y_2} \\ &= \exp\left(\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}\right) \end{aligned} \qquad (3)$$

The following are calibration procedures used for the Wiechert instrument.

Determination of Damping Ratio

Without any change in the adjustment of the seismograph and with the pens writing on the paper, a gentle push is given to the aluminum truss that is connected through one thrust rod to the pendulum mass and through a small telescope rod to one of the pens. A curve like the following will be written by the pen.

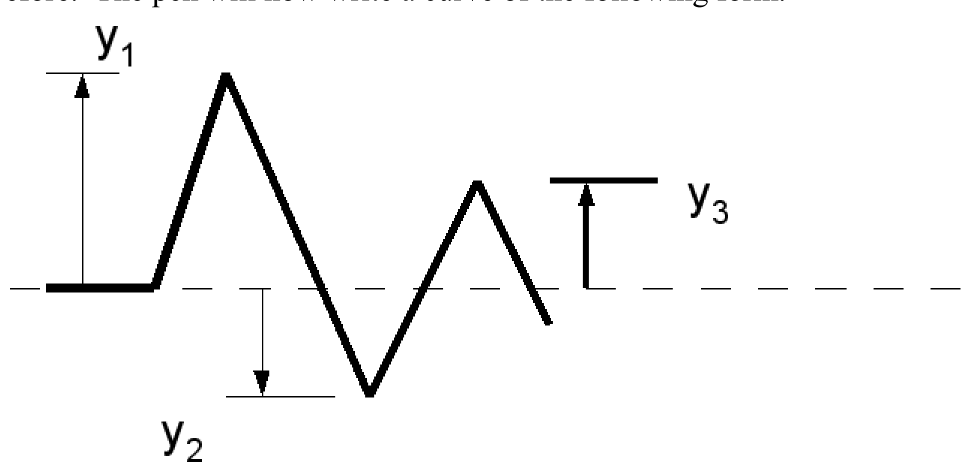


Call the first throw y_1 and the second, much smaller one, y_2. If there were no friction, y_1/y_2 would give us the damping ratio ε. But the effect of friction is equivalently to shift the zero line upward during the stroke from the turning point of y_1 to that of y_2 by a distance r the method of finding which we shall next describe. Hence we correct our observation by subtracting r from y_1 and adding it to y_2. The formula will therefore be

$$\varepsilon = \frac{y_1 - r}{y_2 + r}$$

The Measurement of the Friction

Open the damping cylinder on the one component wide by rotating the lever at the bottom into a position perpendicular to the axis of the cylinder. Give a gentle push to the truss as before. The pen will now write a curve of the following form.



The effect of linear friction is to subtract a constant amount from the amplitude of successive swings. Let the decrease in amplitude for each quarter swing be r. Then, since there are four quarter swings between the turning point of y_1 and that of y_3, the difference $y_1 - y_3$ will be $4r$. Hence we have the formula

$$r = \frac{y_1 - y_3}{4}$$

This holds true for any two successive turning points on the same side. But this difference between amplitudes varies because of differences in the amount and character of the soot on the paper and also because the transverse component is not the same in large and small amplitudes. Hence to obtain a good average we make several such curves and measure all the differences except the last. Let us suppose there are n measurements we may add them all together and divide the sum S by four times the number of observations n.

$$r = \frac{S}{4\text{n}}$$

The quantity r is also half the width of the zone of equilibrium within which the pen will not start again if it comes to rest unless the force be great enough to overcome the static friction. It is furthermore the amount by which the theoretical zero line is shifted in the direction opposite to that in which the pen is moving thus tending to bring the pen to rest sooner. Because of the longer time the friction is operating on each swing in a slow pendulum than in a fast one, the quantity r is not as much a measure of the absolute friction as is $\frac{r}{T_o^2}$. Hence the latter is usually given instead of the former.

Measurement of the Undamped Period T_o

The pens are raised from the smoked paper. The one damping cylinder is left open and the corresponding pen is balanced in the air by placing a small piece of paper near the axis. A gentle push is given to the truss and the time of three of five double swings, to and fro, is taken with a good stop watch. This time divided by the number of swings will be the period. The average of a number of trials is taken.

All the measurements discussed above are to be made for each horizontal component. The same method is used on the vertical.

Finding the Static Magnification

This is most readily done by reduction to the equivalent simple or mathematical pendulum. Let *L* be the length of a simple pendulum that would vibrate with the same period as the respective component of the seismograph does. This length is calculated from the observed period T_o by the formula

$$L = \frac{gT_o^2}{4\pi^2} = 24.82T_o^2$$

Next let *I* be the length of an indicator or weightless pointer attached to the mathematical pendulum and making a frictionless trace as much larger than the motion of the pendulum support as the actual trace amplitude of the seismograph is larger than the amplitude of motion of the earth in a rapid vibration. The latter is what we mean by static magnification. Call it *V*. Then also $V = \frac{I}{L}$

The length of the equivalent indicator is found quite readily.

The case of the horizontal Wiechert

Let a small weight of mass *m* be placed on top of the large mass *M* of the pendulum so that the vertical through the center of gravity *m* and that through the center of gravity *M* are separated by the horizontal distance *d*. It will be sufficient if the small weight is placed with its outer end tangent to that of the larger and *d* put equal to the difference of their radii. Then it can be shown by balancing moments that, if *H* is the height of the center of gravity of the large mass above the hinge and *a* is the amount by which the zero line is shifted by putting on the small weight *m* while the pen is writing on the smoked paper,

$$I = \frac{Mha}{md}$$

Care must be taken to place the center of *m* directly over the thrust rod of the component whose indicator is being measured. The measurement may be made simultaneously for both horizontal components by placing *m* at the edge midway between and reading both deflections a_N and a_E, using for each component the formula

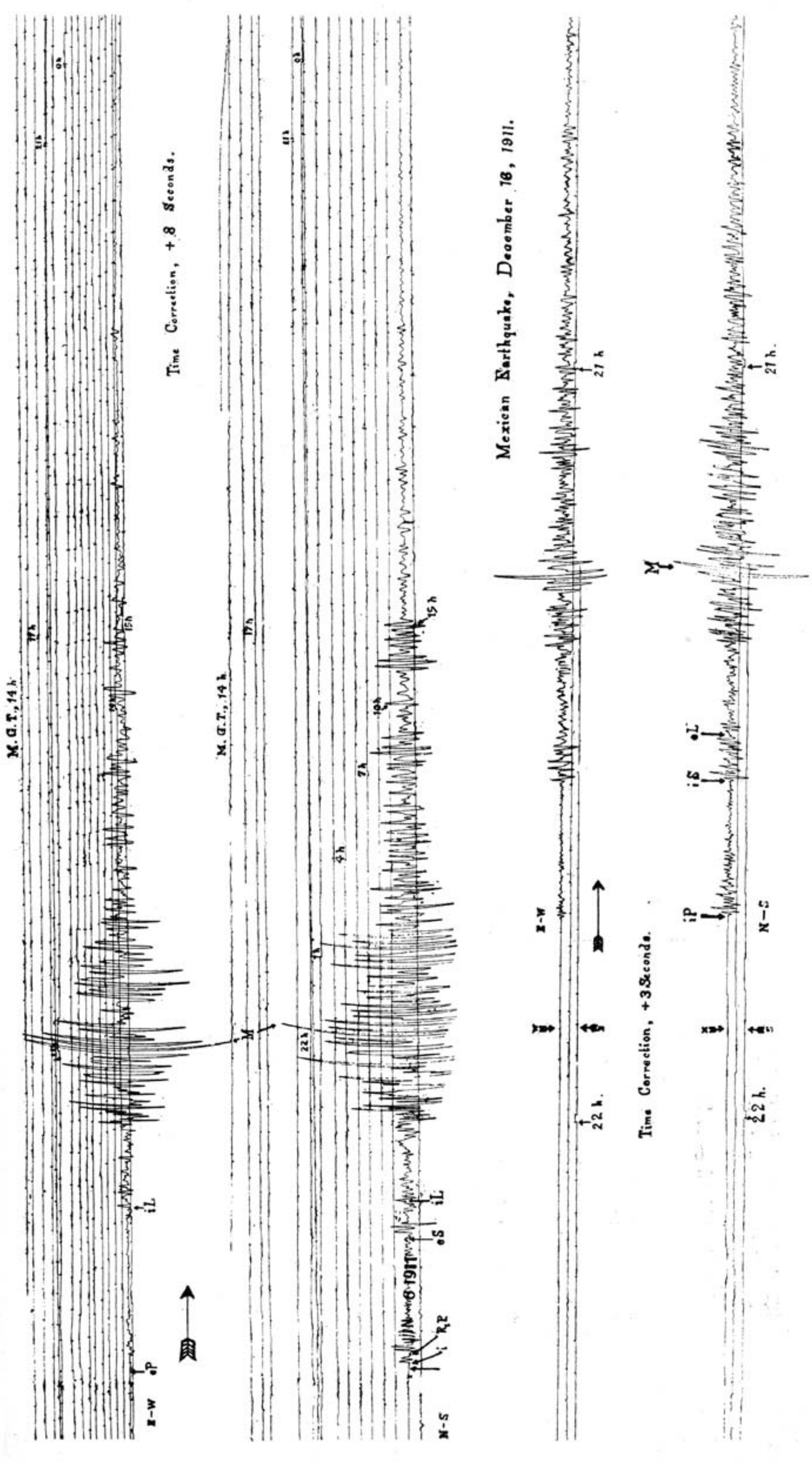
$$I = \frac{0.707MHa}{md}$$

Calibration History SLM Wiechert

Date		NORTH-SOUTH T_o	ε	V	$\frac{r}{T_o^2}$	r	EAST-WEST T_o	ε	V	$\frac{r}{T_o^2}$	r
03 JAN 1911		7.0	5.0	85			7.0	5.4	97		
07 JAN 1911		7.0	5.1	85			7.0	5.1	79		
21 JAN 1911		6.9	5.4	89			6.3	5.0	98		
17 FEB 1911		7.0	5.0	94			7.0	4.9	98		
21 FEB 1911		7.0	5.0	80			7.0	5.0	86		
01 MAY 1911		6.7	4.1	91			7.0	5.7	89		
06 JUN 1911		7.0	5.0	67			7.0	5.0	79		
17 AUG 1911		7.0					7.0				
17 SEP 1911		6.5	5.0	85			7.0	5.0	90		
22 SEP 1911		7.0	5.6	93			7.0	6.2	83		
10 OCT 1911		7.0	5.0	79			7.0	5.0	86		
21 NOV 1911		7.0		88			6.5		84		
17 DEC 1911		6.8	5.0	88			7.0	6.0	83		
18 MAY 1924		6.3									
25 SEP 1925	F	6.1		86	.0038	.14	5.6		78	.0032	.10
25 SEP 1925	L	6.4	5.4	67	.0043	.18	5.4	6.4	72	.0027	.08
05 OCT 1925		6.3	4.2	74	.0061	.24	5.7	5.4	74	.0065	.21
05 OCT 1925		6.3	3.2	74	.0061	.24	5.7	5.0	74	.0065	.21
26 DEC 1925	F	6.4	3.7	75	.0073	.30	5.7	4.9	74	.0081	.26
26 DEC 1925	L	6.4	5.6	75	.0073	.30	5.7	5.5	74	.0081	.26
13 MAR 1926	F	6.1	5.3	86	.0078	.29	5.5	3.6	80	.0162	.49
13 MAR 1926	L	6.1	6.3	86	.0078	.29	5.5	2.7	80	.0162	.49
30 APR 1926	F	6.1	5.6	94	.0067	.25	5.8	4.2	76	.0071	.26
30 APR 1926	L	6.1	4	94	.0067	.25	5.8	3.9	76	.0071	.26
22 JUN 1926	F	6.35	7.0	74	.0055	.22	6.0	5.1	69	.0072	.26
22 JUN 1926	L	6.35	6.9	7.2	.0055	.22	6.0	6.2	69	.0072	.26
14 AUG 1926	F	6.4	8.2	76.1	.0049	.19	5.8	5.2	75.1	.0057	.20
14 AUG 1926	L	6.4	6.9	76.1	.0049	.19	5.8	5.2	75.1	.0057	.20
25 NOV 1926					.088						.095
25 DEC 1926		6.1	7.95	79	.0086	.31	6.0	7.02	75	.0086	.26
03 FEB 1927	F	6.7	7.9	63.6	.0047	.21	5.89	6.2	75.0	.0072	.25
03 FEB 1927	L	6.7	8.0	63.6	.0047	.21	5.89	6.9	75.0	.0072	.25
03 MAR 1927	F	6.2	6.2	72	.0057	.22	6.2	6.7	77	.0054	.21
03 MAR 1927	L	6.2	6.2	72	.0057	.22	6.2	6.2	77	.0054	.21
22 APR 1927	F	6.1	6.3	80	.0035	.13	6.1	6.2	72	.0037	.14
22 APR 1927	L	6.1	6.7	80	.0035	.13	6.1	6.2	72	.0037	.14
23 JUN 1927		6.3	7.3	75	.0056	.22	6.0	6.1	88	.0069	.25
31 AUG 1927	F	6.10	11.0	82.8	.0034	.126	6.06	6.3	79.8	.0034	.124
31 AUG 1927	L	6.10	8.0	82.8	.0034	.126	6.06	6.7	79.8	.0034	.124
08 AUG 1929		6.3	4.8	77	.0025	.10	6.03	5.5	76	.0027	.10
00 JUN 1933		6.2	4.55	81			5.6	6.9	67		
22 APR 1935		6.64	4.88			5.63	5.41		72		
06		5.6	2.64	166		.19	3.6	2.47	173		.19
03 NOV 1937		3.26	2.24	178.2			2.35	1.97	177.7		
01 DEC 1937		4.26		164.59			2.84		164.97		

F constants as found.
L constants after calibration.

Sense of Motion: Viewing the seismogram with increasing time going from left to right, the east-west component is the upper set of traces while the north-south component is the lower set of traces. Trace motion up on the record corresponds to ground motion in the East and South directions.


Mexican Earthquake, June 7, 1911.
Time Correction, +8 Seconds.
M. G. T., 14 h
N-W
N-S
eP
iL
eS
M
15 h
Mexican Earthquake, December 16, 1911.
Time Correction, +3 Seconds.
N-W
N-S
iP
iS
eL
M
21 h
22 h