OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27

5010-108

UNITED STATES GOVERNMENT

Memorandum

File
Sioux Falls.
BLDG - gen

TO : Dean Kleinkopf

DATE: December 8, 1971

FROM : Bob Hazlewood

SUBJECT: Statement concerning damaged water well near Eros Site. South Dakota

Field procedures for all the shotpoints were the same. Shotholes were augured by hand to a depth of 10 feet and one five-pound stick of dynamite was placed in hole and tamped with fill.

The enclosed map shows the location shotpoints. Listed below are the shotpoint numbers, date shot, and distance from the well.

Shotpoint No.	Date Shot	Distance from well
1	Oct. 1, 1970	850 feet
2	Oct. 2, 1970	1060 feet
3	Oct. 2, 1970	1570 feet
12	Oct. 10, 1970	1550 feet
13	Oct. 10, 1970	900 feet
14	Oct. 10, 1970	330 feet
15	Oct. 10, 1970	400 feet
16	Oct. 10, 1970	900 feet
17	Oct. 12, 1970	1000 feet
18	Oct. 12, 1970	1440 feet

I am enclosing copies of a few pages of tables and graphs from, "Seismic effects of quarry blasting", Bulletin 442, U. S. Bureau of Mines (1942) and "Vibrations from construction blasting" by L. Don Leet. I refer to the enclosed copies by page number and figure number as follows:

Page 37, Figure 11 - These measurements were made in a mine on the same rock stratum as the blast and the maximum single amplitude, inch for 8 pounds of explosive at 330 feet was less than .00025 inches. To correct for overburden .00025 x 10 = .0025 maximum single amplitude, inch.

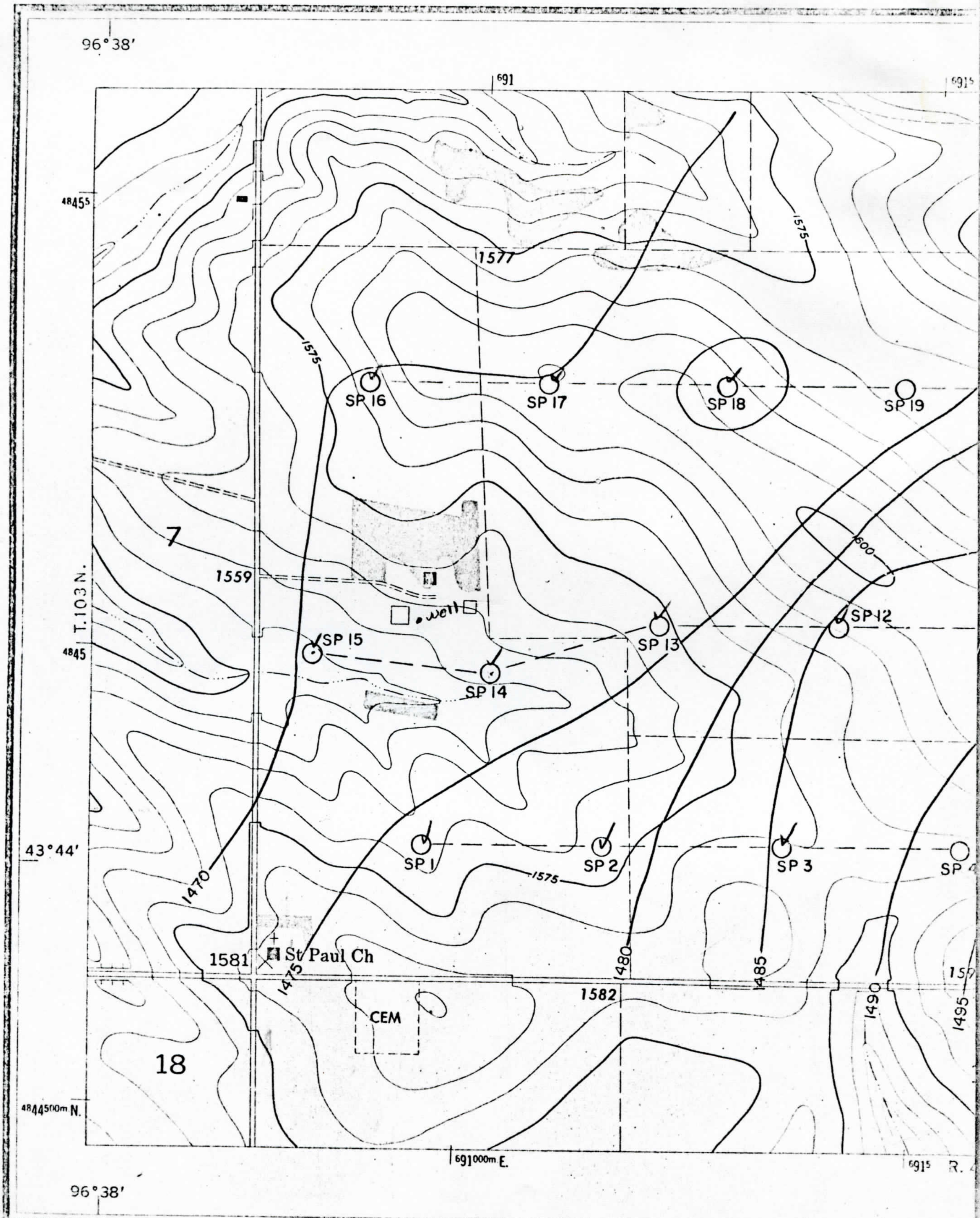
Page 66, Table 6 - Ten pounds of explosives at a distance of 300 feet would show a maximum displacement of .0022 inch and for abnormal deep overburden multiply by 3 = .0066 inch displacement. Using page 20, Table 7 from Leet shows that this would be well below safety factors for any damage.

The line was offset to provide a large margin of safety and I can see no way that a 5-pound shot at a distance of 330 feet would have caused any damage. The crew that assisted on the project recall that water had to be drawn from a cistern at the farmhouse, but cannot recall any explanation of why there was no water in an outlet at the well.

Bob Hazlewood

Bob Hazlewood
Geophysicist

SIOUX FAL



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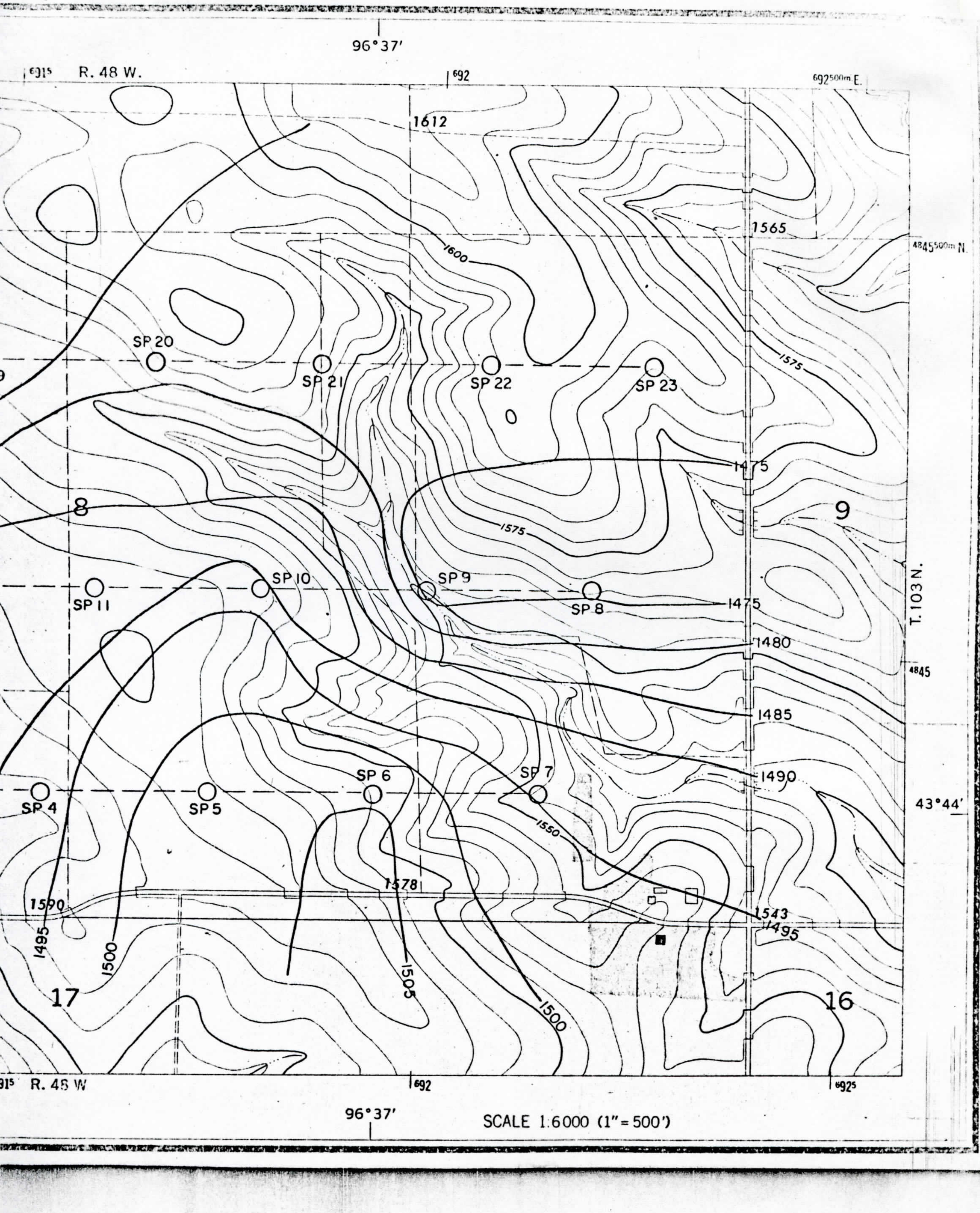

Vibrations from Normal Use

Vibrations from normal use of structures provide a helpful reference level against which to compare vibrations from blasting. Of course, walking on a floor does not always shake an entire house, although slamming a door often does. But the materials of a floor, ceiling, or wall panel of a single room do not know or care whether vibrations to which they are subjected come from that room only, or from a distant point outside the house. And their response to measured vibrations from normal use is a practical guide to their capacity to withstand vibrations from other sources. Displacements of 10-, 20-, or more, thousandths of an inch at frequencies from 5 to 20 cycles per second are not uncommon in dwelling structures from walking, door slamming, and other activities of the occupants.

Elastic Vibrations Related to Quantity of Explosive and Distance

One of the results of extensive experiments by the U. S. Bureau of Mines, as reported in its Bulletin 442 (1942), was development of an empirical formula relating maximum displacement by vibrations to quantity of explosive and distance.

The actual amount of motion in the ground depends not only on the quantity of explosive and distance, but also on the nature of the terrain at the point in question. With the shaking produced by a wave at a given point on rock assigned a coefficient of 1, it has been observed that the same wave at the same point would shake or dis-

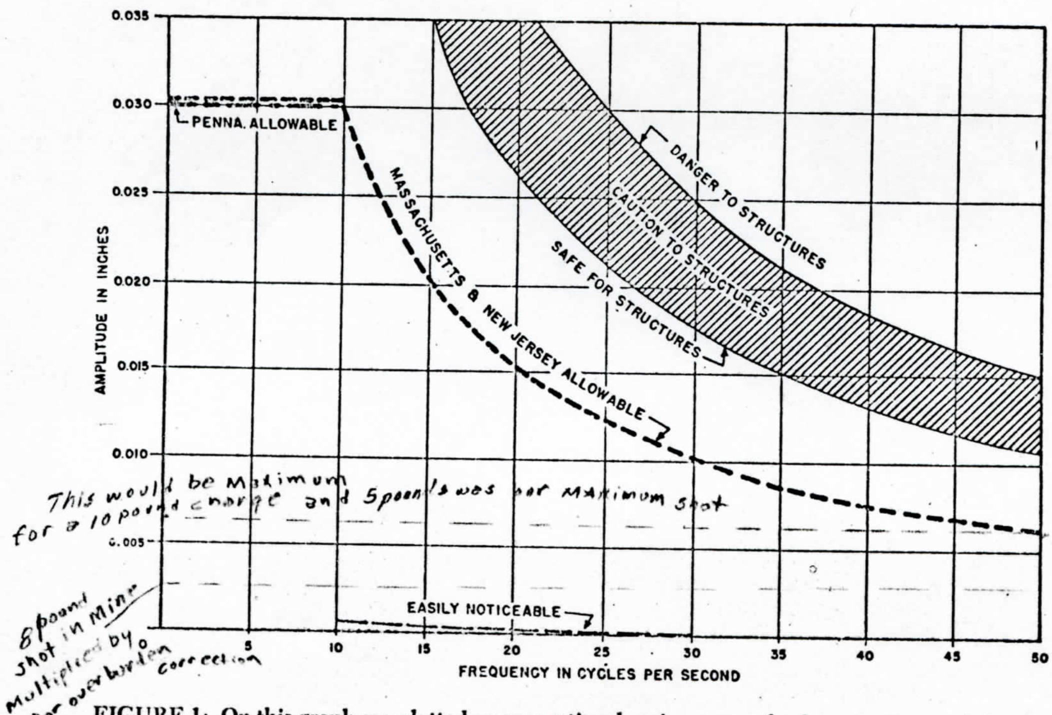

FIGURE 1: On this graph are plotted energy ratios showing areas of safety, caution, and danger for structures, which have been adopted by several authorities concerned with blasting.

Vibrations from Construction Blasting
L. Don Leet

Formula for mine shots:

$$A=\frac{0.035\sqrt{SC}}{D}.$$

If $S=0.6$,

$$A=\frac{0.027\sqrt{C}}{D},$$

where A = maximum single amplitude, inches;
C = weight of explosive, pounds;
D = distance, feet.

This formula probably is best-adapted to predicting vibrations in mines where records are taken on the same rock stratum as the blast.

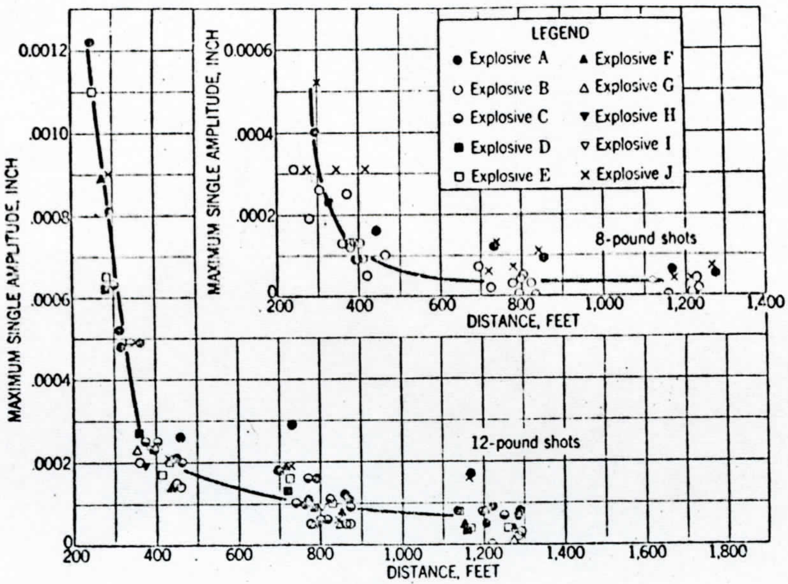

FIGURE 11.—Amplitude-distance curves.

The formula was based upon shots restricted in weight (20 to 200 pounds) and in distance (300 to 1,500 feet); hence the formula should be used only between these limits.

For small weights of explosive (8 and 12 pounds) made under closely controlled conditions, the amplitude varied with the distance, as shown in figure 11. This figure indicates that the amplitude decreased inversely as the 3.6 power of the distance from 200 to 400 feet. From 400 feet to the greatest distance at which records were made—1,300 feet—the amplitude decreased inversely as the distance. This difference illustrates the high damping near the shots.

As the damping in either rock strata or overburden is very rapid at short distances, correct estimation of amplitudes close to a blast is difficult. Table 3 gives a rough idea of the amplitudes in overburden that might be expected 75 feet from a shot.

U.S. Bureau of Mines Bulletin 442 (1942)

TABLE 3.—*Amplitudes at 75 feet*

Weight of explosive, pounds:	*Amplitude, inch*
1	0.001
5	.01
10	.025
50	.10
100	.16

Throughout these derivations the frequency has not been included, because for a given type of ground the predominant frequency is virtually constant; that is, it does not depend on the amplitude. A difference in type of ground (for example, rock outcrop compared to overburden), however, will produce quite a difference in frequencies.

For general use the following frequencies are representative:

	Cycles per second
On outcrops	50
On average overburden	15
On abnormal overburden	5
Residential buildings	10

Abnormal overburden is exceptionally deep overburden (50 feet or more) or overburden composed of a sand-gravel-loam type of deposit.

As the vibrations are generally irregular it should be kept in mind that frequency refers to the predominant frequency. Therefore, sinusoidal conditions can be assumed for computing velocity, energy, etc., only if justified by the seismic records.

SUMMARY

The amplitudes of vibration from quarry and mine blasting can be predicted through application of the following formulas:

(1) For quarries:

Charge, 1,000–15,000 pounds; distance, 500–6,000 feet.
Charge, 100–1,000 pounds; distance, 100–6,000 feet.
Charge, 10–100 pounds; distance, 100–1,000 feet.

$$A = \frac{C^{2/3}}{100}(0.07\epsilon^{-0.00143d} + 0.001),$$

where A = maximum resultant amplitude, inches;
d = distance, feet;
C = explosive charge, pounds.

This amplitude is based upon average overburden. For outcrops, divide amplitude by 10. For deep or abnormal overburden, multiply by 3. (The amplitude on the first story of a house may be taken as equal to that on the ground.)

(2) For mines where the observations are on the same rock stratum:

Shots: 20–200 pounds.
Distance: 300–1,500 feet.

$$A = \frac{0.027\sqrt{C}}{d}.$$

(3) For small shots in mines, the curves of figure 11 can be used.

Shots: 5–15 pounds.
Distance: 200–1,500 feet.

U.S. Bureau of Mines Bulletin 442 (1942)

U.S. Bureau of Mines Bulletin 442 (1942)

TABLE 6.—*Displacement*[1] *for various weights of explosive, inch*

Weight of explosive, pounds	Distance, feet														
	100	200	300	400	500	600	700	800	900	1,000	2,000	3,000	4,000	5,000	6,000
10	0.0029	0.0025	0.0022	0.0019	0.0016	0.0014	0.0013	0.0011	0.0010						
20	.0045	.0039	.0034	.0030	.0026	.0023	.0020	.0017	.0015						
30	.0059	.0052	.0045	.0039	.0034	.0030	.0026	.0022	.0020						
40	.0072	.0063	.0054	.0047	.0041	.0036	.0032	.0027	.0024						
50	.0084	.0073	.0063	.0055	.0048	.0042	.0037	.0032	.0028						
60	.0095	.0082	.0072	.0063	.0054	.0047	.0042	.0036	.0031						
70	.010	.0091	.0079	.0069	.0060	.0052	.0047	.0039	.0035						
80	.011	.0099	.0086	.0075	.0065	.0057	.0051	.0043	.0038						
90	.012	.011	.0093	.0081	.0070	.0061	.0055	.0046	.0041						
100	.013	.012	.010	.0087	.0076	.0066	.0059	.0050	.0044	0.0038	0.0011	0.0004	0.0003	0.0002	0.0002
200	.021	.018	.016	.014	.012	.010	.0094	.0079	.0069	.0060	.0017	.0007	.0004	.0003	.0003
300	.028	.024	.021	.018	.016	.014	.012	.010	.0091	.0079	.0022	.0009	.0005	.0004	.0004
400	.033	.029	.025	.022	.019	.017	.015	.013	.011	.0096	.0027	.0011	.0006	.0005	.0005
500	.039	.034	.029	.026	.022	.019	.017	.015	.013	.011	.0032	.0013	.0008	.0006	.0006
600	.044	.038	.033	.029	.025	.022	.019	.016	.014	.013	.0036	.0014	.0009	.0007	.0007
700	.049	.042	.037	.032	.028	.024	.022	.018	.016	.014	.0039	.0016	.0009	.0008	.0008
800	.053	.046	.040	.035	.030	.026	.024	.020	.017	.015	.0043	.0017	.0010	.0009	.0009
900	.057	.050	.043	.038	.033	.029	.026	.022	.019	.016	.0047	.0019	.0011	.0009	.0009
1,000					.035	.031	.027	.023	.020	.018	.0050	.0020	.0012	.0010	.0010
2,000					.056	.049	.044	.037	.032	.028	.0080	.0032	.0019	.0016	.0016
3,000					.073	.064	.057	.048	.042	.037	.010	.0042	.0025	.0021	.0021
4,000					.089	.078	.069	.059	.051	.045	.013	.0051	.0030	.0025	.0025
5,000					.10	.090	.080	.068	.059	.052	.015	.0058	.0035	.0029	.0029
6,000					.12	.10	.090	.076	.067	.058	.016	.0066	.0040	.0033	.0033
7,000					.13	.11	.10	.085	.074	.065	.018	.0073	.0044	.0036	.0036
8,000					.14	.12	.11	.093	.081	.071	.020	.0080	.0048	.0040	.0040
9,000					.15	.13	.12	.10	.088	.076	.022	.0086	.0052	.0043	.0043
10,000					.16	.14	.13	.11	.094	.082	.023	.0093	.0056	.0046	.0046

[1] Amplitudes are for average overburden (computed from equation 5, p. 35). For outcrops divide amplitude by 10. For abnormal (deep or sand-gravel-loam) overburden multiply by 3.

TABLE 7.—*Acceleration in terms of g*[1]

Displacement, inch	Frequency,[2] cycles per second						
	2	4	6	8	10	15	20
0.24	0.1	0.38	0.86	1.5	2.4	5.4	9.6
.22	.09	.35	.79	1.4	2.2	5.0	8.8
.20	.080	.32	.72	1.3	2.0	4.5	8.0
.18	.072	.29	.65	1.2	1.8	4.1	7.2
.16	.064	.26	.58	1.0	1.6	3.6	6.4
.14	.056	.22	.50	.90	1.4	3.2	5.6
.12	.048	.19	.43	.77	1.2	2.7	4.8
.10	.040	.16	.36	.64	1.0	2.2	4.0
.08	.032	.13	.29	.51	.8	1.8	3.2
.06	.024	.10	.22	.38	.6	1.3	2.4
.04	.016	.06	.14	.26	.4	.9	1.6
.02	.008	.03	.07	.13	.2	.4	.8
.01	.004	.016	.036	.064	.1	.2	.4
.008	.0032	.013	.029	.051	.08	.2	.3
.006	.0024	.010	.022	.038	.06	.1	.2
.004	.0016	.006	.014	.026	.04	.09	.2
.002	.0008	.003	.007	.013	.02	.04	.08
.001	.0004	.0016	.0036	.006	.01	.02	.04
.0008	.0003	.0013	.0029	.005	.008	.02	.03
.0006	.0002	.0010	.0022	.004	.006	.01	.02
.0004	.0002	.0006	.0014	.0026	.004	.01	.016
.0002	.0001	.0003	.0007	.0013	.002	.004	.008
.0001	.0000	.0002	.0004	.0006	.001	.002	.004

[1] Computed from equation 11, p. 63.
[2] Abnormal overburden, 4 to 10 cycles; average overburden, 10 to 20 cycles; outcrop, 20 to 80 cycles.
Representative frequencies: Average overburden, 15 cycles; abnormal overburden, 5 cycles; residential structures, 10 cycles.

On the other hand, an 8,000-pound shot at a distance of 500 feet would be dangerous because from table 6 the amplitude would be 0.14 inch. Table 7 shows that 0.14 inch at 10 cycles produces an acceleration of 1.4 *g*, which is in the damage region.

As a whole, the regions in table 7 are conservative for quarry shots; that is, a combination that results in an acceleration in the damage region may not produce damage. If the combination of weight, distance, and overburden indicates an acceleration in the safe region, however, no damage will occur from ground vibration. The region marked "caution" represents combinations approaching dangerous proportions.

MISCELLANEOUS INVESTIGATIONS

DELAY BLASTING

Several tests were made to ascertain the feasibility of using delay blasting to reduce ground vibrations. Delay blasting is the process of firing a quantity of explosive in two or more sections with an

U.S. Bureau of Mines Bulletin 442 (1942)

Memorandum

To: Bob Hazelwood

From: Dean Kleinkopf

Subject: Damaged water well near EROS site, South Dakota

In accordance with our telephone conversation, I am enclosing memoranda which describe damage to a water well--allegedly caused by our seismic shooting on the EROS site in South Dakota. We need a statement as best you can recall from you and your crew regarding the circumstances, such as: location of the well relative to adjacent shot points (shot point numbers), quantitative statement as to the lateral effect of a 5 lb. charge in such terrain that might cause this kind of damage, the number of blasts at each shot point, and the dates that the shots were made. Perhaps some of your crew can recall whether the well was already dry and particularly why, when you obtained water from the farm, it was drawn from the cistern. I will phone you after you have had an opportunity to cogitate this matter.

Deputy Assistant Chief Geologist
for Geophysics

Enclosure

MDKLEINKOPF:vsb
cc: Director's Read
ACG Read
Kleinkopf Chron
Kleinkopf Subj. File

Don Mabey w/enc.

SEISMIC REFRACTION SURVEY OF PROPOSED EROS SITE IN VICINITY OF SIOUX FALLS, SOUTH DAKOTA

By

R. M. Hazlewood

A seismic refraction survey was made by the U.S. Geological Survey, to determine the depth to bedrock at a proposed EROS Data Center site, about 17 miles northeast of Sioux Falls, South Dakota, in the southern 1/2 of sec. 8, T. 103 N., R. 48 W. in Edison Township, during the period September 29 to October 14, 1970.

The topography of the site is gently rolling with a ridge at an elevation of about 1,600 feet trending northwest-southeast across the central part of the site. The surface elevations range from a low of 1,530 feet to a high of 1,605 feet (fig. 1).

Wind deposited silt covers the surface of the site and contains small amounts of sand and clay. Underlying the silt deposits are till deposits consisting chiefly of unsorted nonstratified boulder clay. Precambrian Sioux Quartzite underlies the till deposits (oral commun., R. M. Lindvall).

The refraction seismic survey was made with a 24-trace portable refraction seismograph. The instrument was mounted in a 4-wheel drive carryall to permit more rapid coverage of the area.

The reversed profile method of shooting was used in making the seismic refraction field measurements. In this method the geophones are arranged in a straight line, and dynamite is detonated alternately at the ends of the line. The profiles were 650 feet in length and the geophones were placed at intervals of 50 feet along the line.

Shot holes were drilled to a depth of 10 feet with a hand auger, and a 5-pound stick of 60 percent high-velocity dynamite, detonated with a seismic cap, provided sufficient energy for good quality records. The location of the seismic lines and shot holes are shown in figure 1.

The depths to bedrock were calculated using standard computational procedures. The results of the survey are shown by a bedrock contour map (fig. 1). The average velocity of the near-surface material is 5,000 feet per second and the bedrock velocity averages 15,000 feet per second.

A subsurface contour map on the top of the Sioux quartzite with a contour interval of 5 feet was prepared from the seismic data (fig. 1). The depth to bedrock as determined from the seismic data ranges from a minimum of 50 feet to a maximum of 122 feet and are shown in table 1. These depths are very compatible with a reported depth of about 100 feet to quartzite in a water well on the farm of Mr. Hegge in the NW1/2SW1/4 sec. 8, at an elevation of 1,565 feet. A water well on the farm of Rudy Forseth in the SE1/4SE1/4 sec. 8 at an elevation of 1,555 reportedly encountered quartzite at a depth of 63 feet.

Table 1.--Depth to bedrock at shotpoints, EROS site.

Shotpoint number	Depth	Surface elevation	Bedrock elevation
1	92	1,568	1,476
2	95	1,572	1,477
3	95	1,580	1,485
4	92	1,584	1,492
5	92	1,595	1,503
6	74	1,580	1,506
7	50	1,545	1,495
8	92	1,566	1,474
9	78	1,552	1,474
10	98	1,582	1,494
11	109	1,596	1,487
12	106	1,592	1,486
13	102	1,574	1,472
14	92	1,563	1,471
15	84	1,554	1,470
16	113	1,583	1,470
17	122	1,592	1,470
18	116	1,592	1,476
19	108	1,579	1,471
20	109	1,588	1,479
21	109	1,585	1,476
22	113	1,592	1,479
23	109	1,585	1,476