```
7540 LOCATE 14,8:PRINT ".1"
7550 LOCATE 20,8:PRINT ".01"
7560 LOCATE 21,12:PRINT "1"
7570 LOCATE 21,32:PRINT "10"
7580 LOCATE 21,52:PRINT "100"
7590 LOCATE 21,72:PRINT "1000"
7600 LOCATE 22,35:PRINT "Scaled Distance (Ds)"
7610 LOCATE 23,19:PRINT"Plot of Data and 95% Confidence Level Line"
7620 LOCATE 11,1:PRINT "Particle"
7630 LOCATE 12,1:PRINT "Velocity"
7640 LOCATE 13,3:PRINT"(PV)"
7650 LOCATE 1,1:PRINT USING "&";DISCRP$(1)
7660 LOCATE 2,1:PRINT USING "&";DISCRP$(2)
7670 LOCATE 3,1:PRINT USING "&";DISCRP$(3)
7680 LOCATE 18,14:PRINT USING "Min. Ds = ###.##";SDMIN
7690 LOCATE 19,14:PRINT USING "Max. Ds = ###.##";SDMAX
7700 REM routine to plot scattered data set
7710 FOR I%=1 TO N%
7720  DST=D(I%)/SQR(W(I%))
7730  XX=.43*LOG(DST)
7740  YY=.43*LOG(VELOC(I%))
7750  IF XX>3 GOTO 7820
7760  IF XX<0 GOTO 7820
7770  IF YY>1 GOTO 7820
7780  IF YY<-2 GOTO 7820
7790  XX=500*XX/3+90
7800  YY=155-130*(YY+2)/3
7810  CIRCLE (XX,YY),2
7820 NEXT I%
7830 REM plot of 95% confidence line within data limits
7840 PV=(B0+B1*LOG(SDMIN))+2*S
7850 PV1=(B0+B1*LOG(SDMAX))+2*S
7860 YY=.434294*PV
7870 YY=155-130*(YY+2)/3
7880 Y1=.434294*PV1
7890 Y1=155-130*(Y1+2)/3
7900 XX=.434294*LOG(SDMIN)
7910 XX=90+500*XX/3
7920 X1=.434294*LOG(SDMAX)
7930 X1=90+500*X1/3
7940 LINE (XX,YY)-(X1,Y1)
7950 REM Define data limits as Dashed lines
7960 YMA=YY-8
7970 FOR I%=1 TO 5
7980  LINE (XX-1,YMA)-(XX,YMA+2),1,BF
7990  YMA=YMA+4
8000 NEXT I%
8010 YMA=Y1-8
8020 FOR I%=1 TO 5
8030  LINE (X1-1,YMA)-(X1,YMA+2),1,BF
8040  YMA=YMA+4
8050 NEXT I%
8060 LOCATE 19,35
8070 PRINT "PV = "
8080 LOCATE 19,40:PRINT USING "###.##";Q
8090 LOCATE 19,46:PRINT"*Ds"
8100 LOCATE 18,49:PRINT USING "##.##";B1
8110 REM Solution for scaled distance for 1.25, 1, and .75 IPS
8120 PV=1.25
8130 GOSUB 4640 'SOLVE SUBROUTINE
8140 IF DS1<SDMIN OR DS1>SDMAX THEN DS1=0
8150 SF125=DS1
```

```
8160 PV=1!
8170 GOSUB 4640 'SOLVE SUBROUTINE
8180 IF DS1<SDMIN OR DS1>SDMAX THEN DS1=0
8190 SF1=DS1
8200 PV=.75
8210 GOSUB 4640 'SOLVE SUBROUTINE
8220 IF DS1<SDMIN OR DS1>SDMAX THEN DS1=0
8230 SF75=DS1
8240 LOCATE 4,62:PRINT"  Dist.        Ds"
8250 LOCATE 5,61:PRINT"==================="
8260 LOCATE 6,62:PRINT"     0-300 "
8270 LOCATE 7,62:PRINT"   301-5000"
8280 LOCATE 8,62:PRINT"Beyond 5000"
8290 LOCATE 6,75:PRINT USING "##.##";SF125
8300 LOCATE 7,75:PRINT USING "##.##";SF1
8310 LOCATE 8,75:PRINT USING "##.##";SF75
8320 LOCATE 24,1:INPUT "",ANS$:SCREEN 0:WIDTH 80: COLOR 15,1,1: CLS: ON ERROR GO
TO 0: RETURN
8330 REM*************************************************************************
8340 REM SUBROUTINE END
8350 LPRINT CHR$(12);
8360 LPRINT USING "The 95% confidence level equation is: PV=####.###(Ds)^##.##";
Q;B1
8370 LPRINT: LPRINT USING "The coefficient of determination (r^2 - 'goodness of
fit') is: #.##";R2
8380 LPRINT:LPRINT:LPRINT "Regression Analysis is complete: refer to above infor
mation, and to printed"
8390 LPRINT "Distance vs. Charge weight tables for all future blast designs."
8400 LPRINT
8410 LPRINT "Modified Scaled Distances should be reviewed and renewed:"
8420 LPRINT "    1. At least once a year."
8430 LPRINT "    2. Whenever geological or geographical site conditions change si
gnificantly."
8440 LPRINT "    3. Whenever blasting methods or blast design changes significant
ly."
8450 RETURN
```

APPENDIX 'A': OSMRE PROGRAM USE

The officially approved OSMRE Computer program is listed in full in IBM BASIC between pages 135 and 149. It will run on the IBM PC, PCjr, AT and XT and most IBM "Compatibles". It may be entered directly from the listing, but to avoid the tedium of this very long entry, and to eliminate possible errors in entry, it is available on disc, in BASIC and FORTRAN, as detailed on page 166.

The program is extremely easy to use, and has been developed specifically to enable non-computer trained personnel to perform the necessary calculations to permit compliance with the requirements of Alternative Scaled Distance applications. It will permit the print-out of entered data as a record of blast vibrations used in the calculations, and will automatically follow the regulations in terms of permissible velocities at different distances. It will permit viewing a plot of the data and the 95% confidence level attenuation curve on the monitor screen, and it provides full data editing and storage/recall from floppy discs. It permits the printing out of a complete Charge Weight/Distance Table for each of the regulatory maximum velocity distance ranges. It also prints out the 95% upper confidence level attenuation formula, together with the coefficient of determination ("goodness of fit") to enable all non-regulatory prediction calculations to be performed.

Following loading the program into the computer, it will be found that the clear prompts, and built-in error protection will enable virtually anyone to follow the proper procedures. The program will not permit extrapolation beyond the limits of the experimental data, although the Charge Weight/Distance Tables will print out "permissible" Charge Weights possibly greatly in excess of the range of collected data. This is because the regulations themselves do not limit charge weights as such, only Scaled Distances, and once a particular scaled distance is permitted, then, strictly speaking, it may be expressed as any combination of distance and charge weight together. For this reason, the user is warned that he must exercise caution and discrimination, and that he should refer to the discussions on this subject on pages 133 and 134, and page 22.

Returning to the exercise on the Blackrock Mine #2 Pit Overburden data, the following pages show a printout from the OSMRE Program, as follows: page 151: "Input data summary", page 152: "OSM Charge Weight Table for 0 - 300 ft.", page 153: "OSM Charge Weight Table for 301 - 5000 ft.", page 154: "OSM Charge Weight Table for 5001 ft. and beyond", and on page 155 the 95% confidence level formula, the "goodness of fit" and a warning on review and renewal.

Appx. 'A': OSMRE program example

Input data summary for:

Blackrock Coal Company, Eaglefeather Mine,
Blackrock Wyorado. September 3, 1986.
#2 Pit Overburden: Alternative Scaled Dist.

NOTE: Scaled Distance for reference only. Page, 1

Line No.	Distance/ft.	Charge/lb.	Peak Velocity/ips	Scaled Dist.*
1	220	230	1.10	14.5
2	800	925	0.36	26.3
3	1200	110	0.02	114.4
4	220	560	1.40	9.3
5	920	690	0.34	35.0
6	1200	420	0.28	58.6
7	2050	245	0.02	131.0
8	1200	85	0.02	130.2
9	800	125	0.17	71.6
10	2050	135	0.01	176.4
11	800	1570	0.86	20.2
12	2050	110	0.01	195.5
13	1200	430	0.28	57.9
14	920	247	0.18	58.5
15	800	250	0.24	50.6
16	460	270	0.84	28.0
17	800	1240	0.48	22.7
18	2050	250	0.03	129.7
19	1200	160	0.04	94.9
20	460	480	0.38	21.0
21	225	530	1.10	9.8
22	460	650	0.50	18.0
23	920	330	0.21	50.6
24	800	745	0.33	29.3
25	460	970	0.98	14.8
26	460	1100	0.94	13.9
27	2050	190	0.02	148.7
28	800	950	0.42	26.0
29	920	260	0.13	57.1
30	800	1530	0.51	20.5
31	800	1160	0.82	23.5

OSM Charge Weight per Delay Table for 0 - 300 ft
based on 31 data pairs for:
Blackrock Coal Company, Eaglefeather Mine,
Blackrock Wyorado. September 3, 1986.
#2 Pit Overburden: Alternative Scaled Dist.

The scaled distance for this distance range is 23.56

Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)
50	5	134	32	218	86
52	5	136	33	220	87
54	5	138	34	222	89
56	6	140	35	224	90
58	6	142	36	226	92
60	6	144	37	228	94
62	7	146	38	230	95
64	7	148	39	232	97
66	8	150	41	234	99
68	8	152	42	236	100
70	9	154	43	238	102
72	9	156	44	240	104
74	10	158	45	242	106
76	10	160	46	244	107
78	11	162	47	246	109
80	12	164	48	248	111
82	12	166	50	250	113
84	13	168	51	252	114
86	13	170	52	254	116
88	14	172	53	256	118
90	15	174	55	258	120
92	15	176	56	260	122
94	16	178	57	262	124
96	17	180	58	264	126
98	17	182	60	266	127
100	18	184	61	268	129
102	19	186	62	270	131
104	19	188	64	272	133
106	20	190	65	274	135
108	21	192	66	276	137
110	22	194	68	278	139
112	23	196	69	280	141
114	23	198	71	282	143
116	24	200	72	284	145
118	25	202	74	286	147
120	26	204	75	288	149
122	27	206	76	290	152
124	28	208	78	292	154
126	29	210	79	294	156
128	30	212	81	296	158
130	30	214	83	298	160
132	31	216	84	300	162

OSM Charge Weight per Delay Table for 301 - 5000 ft
based on 31 data pairs for:
Blackrock Coal Company, Eaglefeather Mine,
Blackrock Wyorado. September 3, 1986.
#2 Pit Overburden: Alternative Scaled Dist.

The scaled distance for this distance range is 26.99

Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)
350 -	168	1900 -	4956	3450 -	16339
400 -	220	1950 -	5220	3500 -	16816
450 -	278	2000 -	5491	3550 -	17300
500 -	343	2050 -	5769	3600 -	17791
550 -	415	2100 -	6054	3650 -	18288
600 -	494	2150 -	6345	3700 -	18793
650 -	580	2200 -	6644	3750 -	19304
700 -	673	2250 -	6949	3800 -	19822
750 -	772	2300 -	7262	3850 -	20347
800 -	879	2350 -	7581	3900 -	20879
850 -	992	2400 -	7907	3950 -	21418
900 -	1112	2450 -	8240	4000 -	21964
950 -	1239	2500 -	8580	4050 -	22516
1000 -	1373	2550 -	8926	4100 -	23076
1050 -	1513	2600 -	9280	4150 -	23642
1100 -	1661	2650 -	9640	4200 -	24215
1150 -	1815	2700 -	10007	4250 -	24795
1200 -	1977	2750 -	10381	4300 -	25382
1250 -	2145	2800 -	10762	4350 -	25976
1300 -	2320	2850 -	11150	4400 -	26576
1350 -	2502	2900 -	11545	4450 -	27184
1400 -	2691	2950 -	11946	4500 -	27798
1450 -	2886	3000 -	12355	4550 -	28419
1500 -	3089	3050 -	12770	4600 -	29047
1550 -	3298	3100 -	13192	4650 -	29682
1600 -	3514	3150 -	13621	4700 -	30324
1650 -	3737	3200 -	14057	4750 -	30972
1700 -	3967	3250 -	14499	4800 -	31628
1750 -	4204	3300 -	14949	4850 -	32290
1800 -	4448	3350 -	15406	4900 -	32959
1850 -	4698	3400 -	15869	4950 -	33635
				5000 -	34318

Although the above charge weights-per-delay are authorized under the regulations, they may exceed, or greatly exceed, practical limitations.

Appx. 'A': OSMRE program example

OSM Charge Weight per Delay Table for 5001 ft and beyond
based on 31 data pairs for:
Blackrock Coal Company, Eaglefeather Mine,
Blackrock Wyorado. September 3, 1986.
#2 Pit Overburden: Alternative Scaled Dist.

The scaled distance for this distance range is 32.16

Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)	Dist(ft)	Charge(lb)
5050 -	24657	7550 -	55113	10050 -	97654
5100 -	25148	7600 -	55845	10100 -	98628
5150 -	25643	7650 -	56582	10150 -	99607
5200 -	26144	7700 -	57324	10200 -	100591
5250 -	26649	7750 -	58071	10250 -	101579
5300 -	27159	7800 -	58823	10300 -	102573
5350 -	27674	7850 -	59580	10350 -	103571
5400 -	28193	7900 -	60341	10400 -	104574
5450 -	28718	7950 -	61107	10450 -	105582
5500 -	29247	8000 -	61878	10500 -	106595
5550 -	29781	8050 -	62654	10550 -	107612
5600 -	30320	8100 -	63435	10600 -	108635
5650 -	30864	8150 -	64220	10650 -	109662
5700 -	31413	8200 -	65011	10700 -	110694
5750 -	31966	8250 -	65806	10750 -	111731
5800 -	32525	8300 -	66606	10800 -	112773
5850 -	33088	8350 -	67411	10850 -	113820
5900 -	33656	8400 -	68221	10900 -	114871
5950 -	34229	8450 -	69035	10950 -	115927
6000 -	34806	8500 -	69855	11000 -	116988
6050 -	35389	8550 -	70679	11050 -	118054
6100 -	35976	8600 -	71508	11100 -	119125
6150 -	36569	8650 -	72342	11150 -	120201
6200 -	37166	8700 -	73181	11200 -	121281
6250 -	37767	8750 -	74024	11250 -	122367
6300 -	38374	8800 -	74873	11300 -	123457
6350 -	38986	8850 -	75726	11350 -	124552
6400 -	39602	8900 -	76584	11400 -	125651
6450 -	40223	8950 -	77447	11450 -	126756
6500 -	40849	9000 -	78315	11500 -	127865
6550 -	41480	9050 -	79187	11550 -	128980
6600 -	42116	9100 -	80065	11600 -	130099
6650 -	42756	9150 -	80947	11650 -	131223
6700 -	43402	9200 -	81834	11700 -	132352
6750 -	44052	9250 -	82726	11750 -	133485
6800 -	44707	9300 -	83623	11800 -	134624
6850 -	45367	9350 -	84524	11850 -	135767
6900 -	46032	9400 -	85431	11900 -	136915
6950 -	46701	9450 -	86342	11950 -	138068
7000 -	47375	9500 -	87258	12000 -	139226
7050 -	48055	9550 -	88179	12050 -	140389
7100 -	48739	9600 -	89105	12100 -	141556
7150 -	49428	9650 -	90035	12150 -	142728
7200 -	50121	9700 -	90971	12200 -	143905
7250 -	50820	9750 -	91911	12250 -	145087
7300 -	51523	9800 -	92856	12300 -	146274
7350 -	52231	9850 -	93806	12350 -	147466
7400 -	52945	9900 -	94761	12400 -	148662
7450 -	53662	9950 -	95720	12450 -	149864
7500 -	54385	10000 -	96685	12500 -	151070

Although the above charge weights-per-delay are authorized under the regulations, they may exceed, or greatly exceed, practical limitations.

Appx. 'A': OSMRE program example

The 95% confidence level equation is: PV= 223.50*(Ds)^-1.64

The coefficient of determination (r^2 - 'goodness of fit') is: 0.91

Regression Analysis is complete: refer to above information, and to printed Distance vs. Charge weight tables for all future blast designs.

Modified Scaled Distances should be reviewed and renewed:

1. At least once a year.
2. Whenever geological or geographical site conditions change significantly.
3. Whenever blasting methods or blast design changes significantly.

APPENDIX 'A': VIBRA-TECH REGRESSION PROGRAM NOTES.

Also available is a rather less sophisticated computer program, written in BASIC. This program can be regarded as complementary to the Approved OSMRE Program, since it is aimed principally at general vibration control and prediction rather than specific OSMRE Regulations compliance. It will permit somewhat greater versatility in performing prediction calculations, and demands greater operator familiarity with prediction techniques. It is not essential for compliance with OSMRE regulations. For identical data input, however, it will arrive at precisely the same 95% confidence level attenuation formula and "goodness of fit", so that mathematically it is equally valid, and can be used for compliance if desired.

The first departure from the OSMRE program occurs when the user is asked to specify square or cube root scaled distance scaling. This to enable regression analyses to be performed on air overpressure. While it is acknowledged that air overpressure predictions have to be made with the utmost caution because of the large number of variables involved, and therefore they should be undertaken only with great care and circumspection, nevertheless it is felt that the ability to examine possibilities in this area should not be denied the operator. If the cube root scaling option is chosen, then vibration unit references continue in terms of PSI rather than in INS/SEC.

Data entry is somewhat different, and no provision is made for data storage to, or recall from, diskettes. Prompts are given for specific name, address, date and operation details entry, and as the program proceeds a printout is made giving a complete record of the analysis. A warning is given at the beginning that at least 30 data pairs should be used, but analysis can be run on considerably less. If analysis is made on less, the printout contains the warning that more data is needed for a valid analysis. At the conclusion of data entry, an opportunity is given for correcting any erroneous entries. Data is printed as entered, and then reprinted as corrected.

The output then follows: the 95% confidence level and the 50% confidence level formulas are given, together with the coefficient of determination and the standard deviation. According to the "goodness" of the coefficient of determination, and depending on the number of data pairs input, appropriate warnings or comments are made. Following this, coordinates for drawing the curves, the 50%, and both upper and lower bound 95% confidence level curves, are given at the maximum and at the minimum scaled distances of the input data. The reason for this is simply that, particularly when communicating with citizen groups where the tendency is to stress "worst-case scenarios", the velocities given are always maximums. Citizen groups, etc., who discuss these velocities forget this in many cases, and it is frequently very useful to be able to point

out that while the worst-case velocities may in fact occur occasionally, perhaps 5% of the time, MOST of the time the velocities will best be indicated by the 50% regression line, while occasionally, perhaps 5% of the time, the velocities may even be as LOW as is indicated by the lower bound curve.

The more significant departure from the OSMRE program now occurs. The user is asked to enter the MAXIMUM DESIRED vibration level. This now has no automatic reference to OSMRE regulations. It may have, if the user is applying for a modified scaled distance formula, or if the user wishes to control his blast vibrations in accordance with the Figure 1 (OSMRE Regulations) Blasting Level Chart. On the other hand, the operator may simply wish to conduct blasting operations as close as possible to one of his own mine installations. If, on the advice of his consultant, it was considered that 4 or even 6 inches per second was a safe maximum velocity, then this is the figure that would be input. Whatever level is chosen, for whatever reason, regulatory or protective, the program then prints out a scaled distance that should result in a velocity not exceeding this. Based on this scaled distance, the program then permits calculations of maximum charge weight against a minimum distance, and minimum distances against a specific charge weight.

The following pages show a printout of a regression analysis performed with the Vibra-Tech program, using the identical data input as the OSMRE program. In this case, however, it is presumed that the user wishes to comply with the Regulations in accordance with the Blasting Level Chart, and that the vibration analyses show that the predominant frequencies lie above 30 Hz. He will therefore choose 2" per second as his maximum permissible velocity, and the derived "safe" scaled distance, and the following calculations, are all based on this maximum velocity.

The regression curve example on page 161, and the "Blaster Aid" curve example on page 162, are self-explanatory. They may be drawn from the output of either of the regression analysis programs (OSMRE providing the upper bound line only) though they are not essential to any prediction or compliance technique, only supportive. The "Blaster Aid" curve simply translates a scaled distance into a Distance vs. Charge Weight per Delay curve, for the convenience of field personnel.

APPENDIX 'A': V-T COMPUTER PROGRAM EXAMPLE

VIBRA-TECH ENGINEERS INC. 8120 N. SHERIDAN BLVD. SUITE 304A
WESTMINSTER, COLORADO 80003. TELEPHONE: (303) 429-1996

****
* LEAST-SQUARES REGRESSION ANALYSIS *
****

Date: 09/03/1985
Company: BLACKROCK COAL COMPANY
Address: EAGLEFEATHER MINE BLACKROCK WYORADO
Operation: #2 PIT OVERBURDEN

* GROUND MOTION ANALYSIS *

31 Data pairs

NO.	DIST	E/MAX	PV
1	220	230	1.1
2	800	925	.36
3	1200	110	.02
4	220	560	1.4
5	920	690	.34
6	1200	420	.28
7	2050	245	.02
8	1200	85	.02
9	800	125	.17
10	2050	135	.01
11	800	1570	.86
12	2050	110	.01
13	1200	430	.28
14	920	247	.18
15	800	250	.24
16	460	270	.84
17	800	1240	.48
18	2050	250	.03
19	1200	160	.04
20	460	480	.38
21	225	530	1.1
22	460	650	.5
23	920	330	.21
24	800	745	.33
25	460	970	.98
26	460	1100	.94
27	2050	190	.02
28	800	950	.42
29	920	260	.13
30	800	1530	.51
31	800	1160	.82

SQUARE ROOT SCALING

E/MAX	DIST	1/2	PV
LBS	FT	Ds	IPS
230	220	14.5	1.1

925	800	26.3	.36
110	1200	114.4	.02
560	220	9.3	1.4
690	920	35	.34
420	1200	58.6	.28
245	2050	131	.02
85	1200	130.2	.02
125	800	71.6	.17
135	2050	176.4	.01
1570	800	20.2	.86
110	2050	195.5	.01
430	1200	57.9	.28
247	920	58.5	.18
250	800	50.6	.24
270	460	28	.84
1240	800	22.7	.48
250	2050	129.7	.03
160	1200	94.9	.04
480	460	21	.38
530	225	9.8	1.1
650	460	18	.5
330	920	50.6	.21
745	800	29.3	.33
970	460	14.8	.98
1100	460	13.9	.94
190	2050	148.7	.02
950	800	26	.42
260	920	57.1	.13
1530	800	20.5	.51
1160	800	23.5	.82

The attenuation formulas are:

PV= 223.502 *(Ds)^-1.641 (95% Confidence level)

PV= 89.473 *(Ds)^-1.641 (50% Confidence level)

Coefficient of determination ('Goodness of fit')= .908 (1.0 = Perfect)

This shows EXCELLENT fit of data: it may be used with confidence

Standard Deviation = .458 (0=PERFECT)

COORDINATES FOR DRAWING CURVE:

At Ds = 9.3 Max. PV = 5.75 Inches per Second (95%+)
At Ds = 9.3 Avg. PV = 2.3 Inches per Second (50%)
At Ds = 9.3 Min. PV = .92 Inches per Second (95%-

At Ds = 100 Max. PV = .117 Inches per Second (95%+)
At Ds = 100 Avg. PV = .047 Inches per Second (50%)
At Ds = 100 Min. PV = .019 Inches per Second (95%-)

At Ds = 195.46 Max. PV = .039 Inches per Second (95%+)
At Ds = 195.46 Avg. PV = .016 Inches per Second (50%)
At Ds = 195.46 Min. PV = .006 Inches per Second (95%-)

V-T computer program example

MAXIMUM desired ground vibration is: 2 inches per second

In order NOT TO EXCEED 2 IPS, use a scaled distance NO LESS than:

< 17.69 >

At a distance of 188 feet, NO MORE THAN:
112 lbs per delay must be fired
in order that 2 ins/second NOT BE EXCEEDED!

At a distance of 351 feet, NO MORE THAN:
393 lbs per delay must be fired
in order that 2 ins/second NOT BE EXCEEDED!

If minimum charge per delay that MUST be fired is:
112 lbs, then it must be AT LEAST
188 feet distant from any critical structure where
2 ins/sec MUST NOT BE EXCEEDED!

If minimum charge per delay that MUST be fired is:
85 lbs, then it must be AT LEAST
164 feet distant from any critical structure where
2 ins/sec MUST NOT BE EXCEEDED!

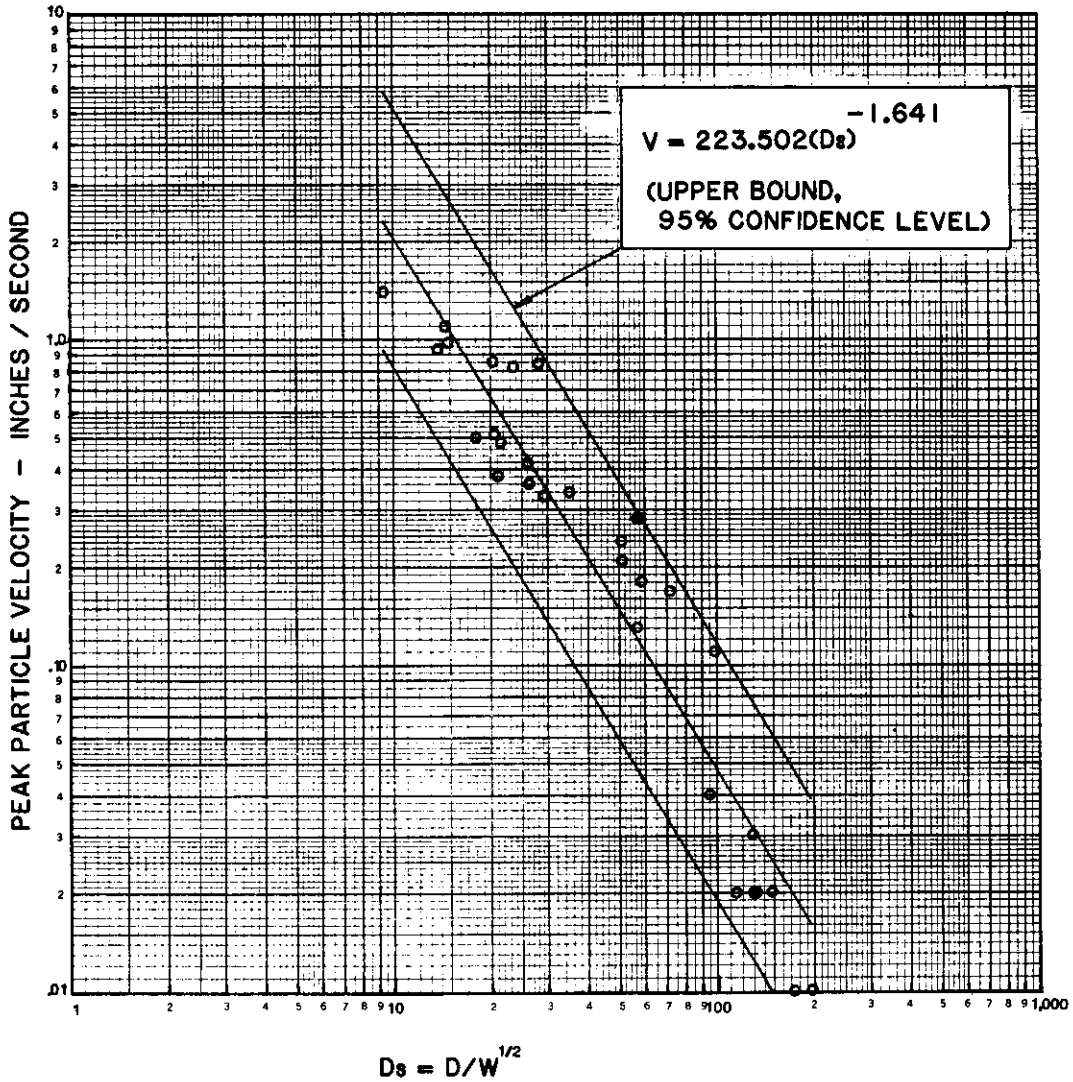
BLACKROCK COAL COMPANY
09/03/1985

VIBRA-TECH ENGINEERS INC.
WESTMINSTER, COLORADO

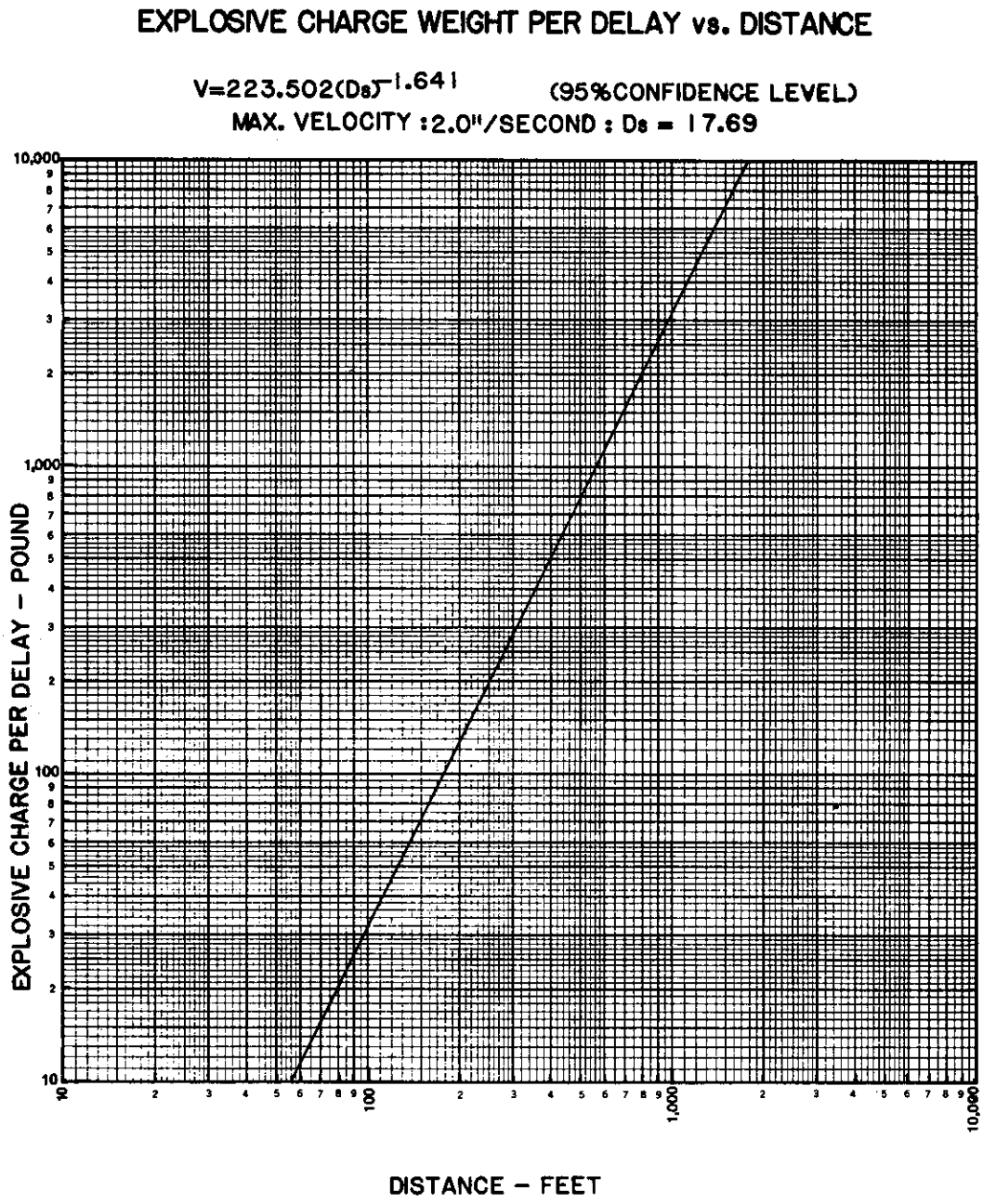
REGRESSION CURVE EXAMPLE

BLACKROCK COAL COMPANY
EAGLEFEATHER MINE
BLACKROCK, WYORADO

VELOCITY ATTENUATION CURVE : 31 data pairs :



'Blaster Aid' curve example



APPENDIX 'A': V-T CALCULATOR PROGRAM

The following calculator program may be used with the Texas Instruments Ti 59 calculator and stored on a magnetic card for ease of further loading. It will require both sides of a standard TI magnetic card. It will provide the 50% probability formula, the standard deviation, the coefficient of determination, and it will calculate PV against Scaled Distance, to a 50% confidence level. It will provide the "Safe" Scaled Distance, to a 95% confidence level, on the input of a maximum desired or allowed particle velocity. Based on this 95% confidence level Scaled Distance, it will calculate maximum charge weight per delay against distance. Following these calculations, the 95% confidence level formula may be determined, since recalling memory register 29 will display the 95% confidence level 'y' axis intercept. Used in conjunction with the formulae provided in Appendix 'B' it will therefore permit full regression analysis, and all necessary calculations required for all OSMRE Regulations compliance and vibration predictions.

Data entry is simply scaled distance versus particle velocity (hence the references throughout the text to "data pairs" - these are the data pairs used in all the calculations), so that the first step is to calculate all scaled distances from the data distances and charge weights. Remember that the computer programs incorporate this calculation, and do not round off the results: if it is wished to compare results from a computer program with the calculator program, scaled distances must be used which are not rounded off. This would not be necessary in normal practice, so this fact might be recalled should the results of any calculations differ slightly. The mathematics are identical, however.

For the first data pair, enter scaled distance, then press "A". Enter the first particle velocity, then press "B". Following each such data pair entry, the display will show the number of data pairs entered. Repeat this procedure for each data pair until all have been entered. Press "C" to calculate the slope, "D" to calculate the 'y' axis intercept, and "E" to calculate the standard deviation. Pressing "E'" will show the coefficient of determination, r^2. Coordinates for the 50% curve may be obtained by entering any scaled distance and pressing "A'", when the display will then show the corresponding particle velocity. Entering any particle velocity that it is desired NOT to exceed, and then pressing "B'", will then display the minimum scaled distance to use. Entering a distance in feet, and then pressing "C'" will calculate the maximum allowable charge per delay based on this scaled distance. As already mentioned, recalling memory register 29 will permit the 95% confidence formula to be determined.

Always use caution, for no guidance or warnings are provided!

```
000  76 LBL
001  11  A
002  23 LNX
003  32 X:T
004  25 CLR
005  91 R/S
006  76 LBL
007  12  B
008  23 LNX
009  78 Σ+
010  91 R/S
011  76 LBL
012  13  C
013  43 RCL
014  01  01
015  65  ×
016  43 RCL
017  04  04
018  55  ÷
019  43 RCL
020  03  03
021  95  =
022  42 STO
023  10  10
024  43 RCL
025  06  06
026  75  -
027  43 RCL
028  10  10
029  95  =
030  42 STO
031  11  11
032  43 RCL
033  04  04
034  33 X²
035  55  ÷
036  43 RCL
037  03  03
038  95  =
039  42 STO
040  12  12
041  43 RCL
042  05  05
043  75  -
044  43 RCL
045  12  12
046  95  =
047  42 STO
048  13  13
049  43 RCL
050  11  11
051  55  ÷
052  43 RCL
053  13  13
054  95  =
055  42 STO
056  14  14
057  91 R/S
058  76 LBL
059  14  D
060  43 RCL
061  04  04
062  55  ÷
063  43 RCL
064  03  03
065  65  ×
066  43 RCL
067  14  14
068  95  =
069  42 STO
070  15  15
071  43 RCL
072  01  01
073  55  ÷
074  43 RCL
075  03  03
076  95  =
077  75  -
078  43 RCL
079  15  15
080  95  =
081  22 INV
082  23 LNX
083  42 STO
084  16  16
085  91 R/S
086  76 LBL
087  15  E
088  43 RCL
089  01  01
090  55  ÷
091  43 RCL
092  14  14
093  95  =
094  42 STO
095  17  17
096  43 RCL
097  04  04
098  75  -
099  43 RCL
100  17  17
101  95  =
102  42 STO
103  18  18
104  43 RCL
105  16  16
106  23 LNX
107  65  ×
108  43 RCL
109  18  18
110  95  =
111  75  -
112  43 RCL
113  06  06
114  95  =
115  42 STO
116  19  19
117  43 RCL
118  14  14
119  65  ×
120  02  2
121  65  ×
122  43 RCL
123  19  19
124  95  =
125  42 STO
126  20  20
127  43 RCL
128  16  16
129  23 LNX
130  33 X²
131  42 STO
132  21  21
133  43 RCL
134  03  03
135  35 1/X
136  42 STO
137  22  22
138  43 RCL
139  14  14
140  33 X²
141  65  ×
142  43 RCL
143  05  05
144  85  +
145  43 RCL
146  02  02
147  85  +
148  43 RCL
149  20  20
```

```
150  95  =
151  65  ×
152  43 RCL
153  22  22
154  95  =
155  85  +
156  43 RCL
157  21  21
158  95  =
159  34 ΓX
160  42 STO
161  23  23
162  91 R/S
163  76 LBL
164  10 E'
165  43 RCL
166  11  11
167  33 X²
168  42 STO
169  24  24
170  43 RCL
171  01  01
172  33 X²
173  55  ÷
174  43 RCL
175  03  03
176  95  =
177  42 STO
178  25  25
179  43 RCL
180  02  02
181  75  -
182  43 RCL
183  25  25
184  95  =
185  65  ×
186  43 RCL
187  13  13
188  95  =
189  42 STO
190  26  26
191  43 RCL
192  24  24
193  55  ÷
194  43 RCL
195  26  26
196  95  =
197  91 R/S
198  76 LBL
199  16 A'
200  42 STO
201  27  27
202  43 RCL
203  16  16
204  65  ×
205  53  (
206  43 RCL
207  27  27
208  45 Y×
209  43 RCL
210  14  14
211  54  )
212  95  =
213  91 R/S
214  76 LBL
215  17 B'
216  42 STO
217  28  28
218  53  (
219  53  (
220  43 RCL
221  23  23
222  65  ×
223  02  2
224  54  )
225  22 INV
226  23 LNX
227  65  ×
228  43 RCL
229  16  16
230  54  )
231  42 STO
232  29  29
233  53  (
234  43 RCL
235  28  28
236  55  ÷
237  43 RCL
238  29  29
239  54  )
240  45 Y×
241  43 RCL
242  14  14
243  35 1/X
244  95  =
245  42 STO
246  30  30
247  91 R/S
248  76 LBL
249  18 C'
250  42 STO
251  31  31
252  53  (
253  43 RCL
254  31  31
255  55  ÷
256  43 RCL
257  30  30
258  54  )
259  33 X²
260  95  =
261  91 R/S
```

COMPUTER AND CALCULATOR PROGRAM AVAILABILITY

The three computer/calculator programs described in Appendix 'A' of this manual are:

1. The OSMRE Approved Regression Analysis Computer Program. This program, written by OSMRE engineers, is designed specifically to permit compliance with the Modified Scaled Distance Option, [(Section 816.67(d)(3)(ii)]. It will also permit compliance with other options, since it provides the 95% upper confidence level vibration attenuation formula from which all other prediction calculations may be made. It will permit data storage onto disc, and data retrieval from disc. It will run on IBM PC and compatibles. The program is written in BASIC and FORTRAN on a 5¼" Floppy Diskette, and includes full instructions for use.

2. The V-T "General Use" Regression Analysis Computer Program. This program is not specific to any particular OSMRE Regulations compliance option, but permits more versatile prediction and control. It will also permit full OSMRE compliance. It does not provide for data storage or retrieval on disc. It will run on IBM PC and compatibles. The program is written in BASIC only on a 5¼" Floppy Diskette, and includes full instructions for use.

3. The V-T Regression Analysis Program for the Ti59 Calculator. This is a simplified calculator program that will permit both OSMRE Regulations compliance and prediction and control, since it will provide the 95% confidence level attenuation formula. The program is stored on a Ti Magnetic Card, and includes full instructions for use.

Any of the above may be obtained by calling the following toll-free number:

1-800-233-6181

APPENDIX 'B'

USEFUL FORMULAE

USEFUL FORMULAE

1. SCALED DISTANCE RELATIONSHIPS:

$$Ds = D/W^{\frac{1}{2}} \qquad W = (D/Ds)^2 \qquad D = Ds \times W^{\frac{1}{2}}$$

Where D = distance, feet; and W = charge weight per delay, lbs.

2. VELOCITY ATTENUATION CURVE RELATIONSHIPS:

$$PV = H \times (Ds)^{-\beta} \qquad Ds = (H/V)^{1/\beta}$$

Where H = y axis intercept @ Ds = 1 and β = slope.

3. AIR OVERPRESSURE :

$$dB = 20 \log (P/Po)$$

where P = OVERPRESSURE, P.S.I.

and $Po = 2.9 \times 10^{-9}$ (base reference pressure).

4. GENERAL: SEISMIC MOTION:

$$PV = 2\pi fA$$

where f = frequency, Hz

A = single displacement, ins.

$$A = \frac{PV}{2\pi f}$$

$$f = \frac{PV}{2\pi A} \qquad VR = (L^2 + V^2 + T^2)^{\frac{1}{2}}$$

NOTE: TRUE Resultant: Waveform must be searched to find Max VR, where L, V, & T all occur at the same instant, otherwise VR is PSEUDO Resultant.

$$ER = 0.274\ VR^2$$ ("Energy Ratio")

5. ACCELERATION:

$$g = \frac{2\pi fV}{386}; \quad g = \frac{4\pi^2 f^2 A}{386}; \quad PV = \frac{386g}{2\pi f}$$

APPENDIX 'C'

GLOSSARY

GLOSSARY

From Bureau of Mines Information Circular IC 8925, 1983.

ACOUSTICAL IMPEDANCE. -The mathematical expression characterizing a material as to its energy transfer properties. The product of its unit density and its sonic velocity.

ADOBE CHARGES. -See mud cap.

AIRBLAST. -An airborne shock wave resulting from the detonation of explosives. May be caused by burden movement or the release of expanding gas into the air. Airblast may or may not be audible.

AIRDOX. -A system that uses 10,000 psi compressed air to break undercut coal. Airdox will not ignite a gassy or dusty atmosphere.

ALUMINUM. -A metal commonly used as a fuel or sensitizing agent in explosives and blasting agents. Normally used in finely divided particle or flake form.

AMERICAN TABLE OF DISTANCES. -A quantity/distance table published by IME as Pamphlet No. 2, which specifies safe explosive storage distances from inhabited buildings, public highways, passenger railways and other stored explosives materials.

AMMONIUM NITRATE (AN). -The most commonly used oxidizer in explosives and blasting agents. Its formula is NH_4NO_3.

ANFO. -An explosive material consisting of ammonium nitrate and fuel oil. The most commonly used blasting agent.

AXIAL PRIMING. -A system for priming blasting agents in which a core of priming material extends through most or all of the blasting agent charge length.

BACK BREAK. -Rock broken beyond the limits of the last row of holes.

BACK HOLES. -The top holes in a tunnel or drift round.

BASE CHARGE. -The main explosive charge in a detonator.

BATF. -Bureau of Alcohol, Tobacco and Firearms, U.S. Department of the Treasury, which enforces explosives control and security regulations.

BEDS OR BEDDING. -Layers of sedimentary rock, usually separated by a surface of discontinuity. As a rule, the rock can be readily separated along these planes.

BENCH. -The horizontal ledge in a quarry face along which holes are drilled vertically. Benching is the process of excavating whereby terraces or ledges are worked in a stepped sequence.

BINARY EXPLOSIVE. -An explosive based on two nonexplosive ingredients, such as nitromethane and ammonium nitrate, which are shipped and stored separately and mixed at the jobsite to form a high explosive.

BLACK POWDER. -A low explosive consisting of sodium or potassium nitrate, carbon, and sulfur. Black powder is seldom used today because of its low energy, poor fume quality, and extreme sensitivity to sparks.

BLAST. -The detonation of explosives to break rock.

BLAST AREA. -The area near a blast within the influence of flying rock missiles, or concussion.

BLASTER. -A qualified person in charge of a blast. Also, a person (blaster-in-charge) who has passed a test, approved by OSM, which certifies his or her qualifications to supervise blasting activities.

BLASTERS' GALVANOMETER; BLASTERS' MULTIMETER. -See galvanometer; multimeter.

BLASTHOLE. -A hole drilled in rock or other material for the placement of explosives.

BLASTING AGENT. -An explosive that meets prescribed criteria for insensitivity to initiation. For storage, any material or mixture consisting of a fuel and oxidizer, intended for blasting, not otherwise defined as an explosive, provided that the finished product, as mixed and packaged for use or shipment, cannot be detonated by means of a No. 8 test blasting cap when unconfined (BATF). For transportation, a material designed for blasting which has been tested in accordance with CFR49, Section 173.14a, and found to be so insensitive that there is very little probability of accidental initiation to explosion or transition from deflagration to detonation (DOT).

BLASTING CAP. -A detonator that is initiated by safety fuse (MSHA). See also detonator.

BLASTING CIRCUIT. -The electrical circuit used to fire one or more electric blasting caps.

BLASTING CREW. -A group of persons whose purpose is to load explosive charges.

BLASTING MACHINE. -Any machine built expressly for the purpose of energizing electric blasting caps or other types of initiator.

BLASTING MAT. -See mat.

BLASTING SWITCH. -A switch used to connect a power source to a blasting circuit.

BLISTERING. -See mud cap.

BLOCKHOLE. -A hole drilled into a boulder to allow the placement of a small charge to break the boulder.

BOOSTER. -A unit of explosive or blasting agent used for perpetuating or intensifying an explosive reaction. A booster does not contain an initiating device but is often cap sensitive.

BOOTLEG. -That portion of a borehole that remains relatively intact after having been charged with explosive and fired. A bootleg may contain unfired explosive and should be considered hazardous.

BOREHOLE (Blasthole). -A drilled hole, usually in rock, into which explosives are loaded for blasting.

BOREHOLE PRESSURE. -The pressure which the hot gases of detonation exert on the borehole wall. Borehole pressure is primarily a function of the density of the explosive and the heat of explosion.

BRIDGE WIRE. -A very fine filament wire imbedded in the ignition element of an electric blasting cap. An electric current passing through the wire causes a sudden heat rise, causing the ignition element to be ignited.

BRISANCE. -A property of an explosive roughly equivalent to detonation velocity. An explosive with a high detonation velocity has high brisance.

BUBBLE ENERGY. -The expanding gas energy of an explosive, as measured in an underwater test.

BULK MIX. -A mass of explosive material prepared for use without packaging.

BULK STRENGTH. -A strength of an explosive per unit volume.

BULLDOZE. -See mud cap.

BURDEN. -The distance from an explosive charge to the nearest free or open face. Technically, there may be an apparent burden and a true burden, the latter being measured in the direction in which displacement of broken rock will occur following firing of the explosive charge. Also, the amount of material to be blasted by a given hole, given in tons or cubic yards.

BURN CUT. -A parallel hole cut employing several closely spaced blastholes. Not all of the holes are loaded with explosive. The cut creates a cylindrical opening by shattering the rock.

BUS WIRES. -The two wires, joined to the connecting wire, to which the leg wires of the electric caps are connected in a parallel circuit. Each leg wire of each cap is connected to a different bus wire. In a series-in-parallel circuit, each end of each series is connected to a different bus wire.

BUTT. -See bootleg.

CAP. -See detonator.

CAPPED FUSE. -A length of safety fuse to which a blasting cap has been attached.

CAPPED PRIMER. -A package or cartridge of cap-sensitive explosive which is specifically designed to transmit detonation to other explosives and which contains a detonator (MSHA).

CAP SENSITIVITY. -The sensitivity of an explosive to initiation, expressed in terms of an IME No. 8 test detonator or a fraction thereof.

CARBON MONOXIDE. - A poisonous gas created by detonating explosive materials. Excessive carbon monoxide is caused by an inadequate amount of oxygen in the explosive mixture (excessive fuel).

CARDOX. -A system that uses a cartridge filled with liquid carbon dioxide, which, when initiated by a mixture of potassium perchlorate and charcoal, creates a pressure adequate to break undercut coal.

CARTRIDGE. -A rigid or semirigid container of explosive or blasting agent of a specified length or diameter.

CARTRIDGE COUNT. -The number of 1¼- by 8-in. cartridges of explosives per 50-lb case.

CARTRIDGE STRENGTH. -A rating that compares a given volume of explosive with an equivalent volume of straight nitroglycerin dynamite, expressed as a percentage.

CAST PRIMER. -A cast unit of explosive, usually pentolite or composition B, commonly used to initiate detonation in a blasting agent.

CHAMBERING. -The process of enlarging a portion of blasthole (usually the bottom) by firing a series of small explosive charges. Chambering can also be done by mechanical or thermal methods.

CHAPMAN-JOUQUET (C-J) PLANE. -In a detonating explosive column, the plane that defines the rear boundary of the primary reaction zone.

CIRCUIT TESTER. -See galvanometer; multimeter.

CLASS A EXPLOSIVE. -Defined by the U.S. Department of Transportation (DOT) as an explosive that possesses detonating or otherwise maximum hazard; such as, but not limited to, dynamite, nitroglycerin, lead azide, black powder, blasting caps, and detonating primers.

CLASS B EXPLOSIVE. -Defined by DOT as an explosive that possesses flammable hazard; such as, but not limited to, propellant explosives, photographic flash powders, and some special fireworks.

CLASS C EXPLOSIVE. -Defined by DOT as an explosive that contains Class A or Class B explosives, or both as components but in restricted quantities. For example, blasting caps or electric blasting caps in lots of less than 1,000.

COLLAR. -The mouth or opening of a borehole or shaft. To collar in drilling means the act of starting a borehole.

COLLAR DISTANCE. -The distance from the top of the powder column to the collar of the blasthole, usually filled with stemming.

COLUMN CHARGE. -A long, continuous charge of explosive or blasting agent in a borehole.

COMMERCIAL EXPLOSIVES. -Explosives designed and used for commercial or industrial, rather than military applications.

COMPOSITION B. -A mixture of RDX and TNT which, when cast, has a density of 1.65 g/cu cm and a velocity of 25,000 fps. It is useful as a primer for blasting agents.

CONDENSER-DISCHARGE BLASTING MACHINE. -A blasting machine that uses batteries or magnets to energize one or more condensers (capacitors) whose stored energy is released into a blasting circuit.

CONFINED DETONATION VELOCITY. -The detonation velocity of an explosive or blasting agent under confinement, such as in a borehole.

CONNECTING WIRE. -A wire, smaller in gage than the lead wire, used in a blasting circuit to connect the cap circuit with the lead wire or to extend leg wires from one borehole to another. Usually considered expendable.

CONNECTOR. -See MS connector.

CONTROLLED BLASTING. -Techniques used to control overbreak and produce a competent final excavation wall. See line drilling, presplitting, smooth blasting, and cushion blasting.

CORDEAU DETONANT FUSE. -A term used to define detonating cord.

CORNISH CUT. -See parallel hole cut.

COROMANT CUT. -See parallel hole cut.

COUPLING. -The degree to which an explosive fills the borehole. Bulk loaded explosives are completely coupled. Untamped cartridges are decoupled. Also, capacitive and inductive coupling from powerlines, which may be introduced into an electric blasting circuit.

COYOTE BLASTING. -The practice of driving tunnels horizontally into a rock face at the foot of the shot. Explosives are loaded into these tunnels. Coyote blasting is used where it is impractical to drill vertically.

CRITICAL DIAMETER. -For any explosive, the minimum diameter for propagation of a stable detonation. Critical diameter is affected by confinement, temperature, and pressure on the explosive.

CROSSLINKING AGENT. -The final ingredient added to a water gel or slurry, causing it to change from a liquid to a gel.

CURRENT LIMITING DEVICE. -A device used to prevent arcing in electric blasting caps by limiting the amount or duration of current flow. Also used in a blaster's galvanometer or multimeter to assure a safe current output.

CUSHION BLASTING. -A surface blasting technique used to produce competent slopes. The cushion holes, fired after the main charge, have a reduced spacing and employ decoupled charges.

CUSHION STICK. -A cartridge of explosive loaded into a small-diameter borehole before the primer. The use of a cushion stick is not generally recommended because of possible resulting bootlegs.

CUT. -An arrangement of holes used in underground mining and tunnel blasting to provide a free face to which the remainder of the round can break. Also the opening created by the cut holes.

CUTOFFS. -A portion of a column of explosives that has failed to detonate owing to bridging or a shifting of the rock formation, often due to an improper delay system. Also a cessation of detonation in detonating cord.

DEAD PRESSING. -Desensitization of an explosive, caused by pressurization. Tiny air bubbles, required for sensitivity, are literally squeezed from the mixture.

DECIBEL. -The unit of sound pressure commonly used to measure airblast from explosives. The decibel scale is logarithmic.

DECK. -A small charge or portion of a blasthole loaded with explosives which is separated from other charges by stemming or an air cushion.

DECOUPLING. -The use of cartridged products significantly smaller in diameter than the borehole. Decoupled charges are normally not used except in cushion blasting, smooth blasting, presplitting, and other situations where crushing is undesirable.

DEFLAGRATION. -A subsonic but extremely rapid explosive reaction accompanied by gas formation and borehole pressure, but without shock.

DELAY BLASTING. -The use of delay detonators or connectors that cause separate charges to detonate at different times, rather than simultaneously.

DELAY CONNECTOR. -A nonelectric, short-interval delay device for use in delaying blasts that are initiated by detonating cord.

DELAY DETONATOR. -A detonator, either electric or nonelectric, with a built-in element that creates a delay between the input of energy and the explosion of the detonator.

DELAY ELECTRIC BLASTING CAP. -An electric blasting cap with a built-in delay that delays cap detonation in predetermined time intervals, from milliseconds up to a second or more, between successive delays.

DELAY ELEMENT. -That portion of a blasting cap which causes a delay between the instant of application of energy to the cap and the time of detonation of the base charge of the cap.

DENSITY. -The weight per unit volume of explosive, expressed as cartridge count or grams per cubic centimeter. See loading density.

DEPARTMENT OF TRANSPORTATION (DOT). -A Federal agency that regulates safety in interstate shipping of explosives and other hazardous materials.

DETALINE SYSTEM. -A nonelectric system for initiating blasting caps in which the energy is transmitted through the circuit by means of a low-energy detonating cord.

DETONATING CORD. -A plastic-covered core of high-velocity explosives, usually PETN, used to detonate charges of explosives. The plastic covering, in turn, is covered with various combinations of textiles and waterproofing.

DETONATION. -A supersonic explosive reaction that propagates a shock wave through the explosive accompanied by a chemical reaction that furnishes energy to sustain the shock wave propagation in a stable manner. Detonation creates both a detonation pressure and a borehole pressure.

DETONATION PRESSURE. -The head-on pressure created by the detonation proceeding down the explosive column. Detonation pressure is a function of the explosive's density and the square of its velocity.

DETONATION VELOCITY. -See velocity.

DETONATORS. -Any device containing a detonating charge that is used to initiate an explosive. Includes, but is not limited to, blasting caps, electric blasting caps, and nonelectric instantaneous or delay blasting caps.

DITCH BLASTING. -See propagation blasting.

DOT. -See Department of Transportation.

DOWNLINE. -The line of detonating cord in the borehole which transmits energy from the trunkline down the hole to the primer.

DRILLING PATTERN. -See pattern.

DROP BALL. -Known also as a headache ball. An iron or steel weight held on a wire rope which is dropped from a height onto large boulders for the purpose of breaking them into smaller fragments.

DYNAMITE. -The high explosive invented by Alfred Nobel. Any high explosive in which the sensitizer is nitroglycerin or a similar explosive oil.

ECHELON PATTERN. -A delay pattern that causes the true burden, at the time of detonation, to be at an oblique angle from the original free face.

ELECTRIC BLASTING CAP. -A blasting cap designed to be initiated by an electric current.

ELECTRIC STORM. -An atmospheric disturbance of intense electrical activity presenting a hazard in all blasting activities.

EMULSION. -An explosive material containing substantial amounts of oxidizers dissolved in water droplets surrounded by an immiscible fuel. Similar to a slurry in some respects.

EXPLODING BRIDGE WIRE (EBW). -A wire that explodes upon application of current. It takes the place of the primary explosive in an electric detonator. An exploding bridge wire detonator is an electric detonator that employs an exploding bridge wire rather than a primary explosive. An exploding bridge wire detonator functions instantaneously.

EXPLOSION. -A thermochemical process in which mixtures of gases, solids or liquids react with the almost instantaneous formation of gaseous pressures and sudden heat release.

EXPLOSION PRESSURE. -See borehole pressure.

EXPLOSIVE. -Any chemical mixture that reacts at high velocity to liberate gas and heat, causing very high pressures. BATF classifications include high explosives and low explosives. Also, any substance classified as an explosive by DOT.

EXPLOSIVE MATERIALS. -A term which includes, but is not necessarily limited to, dynamite and other high explosives, slurries, water gels, emulsions, blasting agents, black powder, pellet powder, initiating explosives, detonators, safety fuses, squibs, detonating cord, igniter cord, and igniters.

EXTRA DYNAMITE. -Also called ammonia dynamite, a dynamite that derives the major portion of its energy from ammonium nitrate.

EXTRANEOUS ELECTRICITY. -Electrical energy, other than actual firing current, which may be a hazard with electric blasting caps. Includes stray current, static electricity, lightning, radio-frequency energy, and capacitive or inductive coupling.

FACE. -A rock surface exposed to air. Also called a free face, a face provides the rock with room to expand from fragmentation.

FIRING CURRENT. -Electric current purposely introduced into a blasting circuit for the purpose of initiation. Also, the amount of current required to activate an electric blasting cap.

FIRING LINE. -A line, often permanent, extending from the firing location to the electric blasting cap circuit. Also called lead wire.

FLASH OVER. -Sympathetic detonation between explosive charges or between charged blastholes.

FLYROCK. -Rock that is propelled through the air from a blast. Excessive flyrock may be caused by poor blast design or unexpected zones of weakness in the rock.

FRACTURING. -The breaking of rock with or without movement of the broken pieces.

FRAGMENTATION. -The extent to which a rock is broken into pieces by blasting. Also the act of breaking rock.

FUEL. -An ingredient in an explosive which reacts with an oxidizer to form gaseous products of detonation.

FUEL OIL. -The fuel, usually No. 2 diesel fuel, in AN-FO.

FUME CLASSIFICATION. -An IME quantification of the amount of fumes generated by an explosive of blasting agent.

FUME QUALITY. -A measure of the toxic fumes to be expected when a specific explosive is properly detonated. See fumes.

FUMES. -Noxious or poisonous gases liberated from a blast. May be due to a low fume quality explosive or inefficient detonation.

FUSE. -See safety fuse.

FUSE LIGHTER. -A pyrotechnic device for rapid and dependable lighting of safety fuse.

GALVANOMETER. -(More properly called blasters' galvanometer.) A measuring instrument containing a silver chloride cell and/or a current limiting device which is used to measure resistance in an electric blasting circuit. Only a device specifically identified as a blasting galvanometer or blasting multimeter should be used for this purpose.

GAP SENSITIVITY. -A measure of the distance across which an explosive can propagate a detonation. The gap may be air or a defined solid material. Gap sensitivity is a measure of the likelihood of sympathetic propagation.

GAS DETONATION SYSTEM. -A system for initiating caps in which the energy is transmitted through the circuit by means of gas detonation inside a hollow plastic tube.

GELATIN. -An explosive or blasting agent that has a gelatinous consistency. The term is usually applied to a gelatin dynamite but may also be a water gel.

GELATIN DYNAMITE. -A highly water-resistant dynamite with a gelatinous consistency.

GENERATOR BLASTING MACHINE. -A blasting machine operated by vigorously pushing down a rack bar or twisting a handle. Now largely replaced by condenser discharge blasting machines.

GRAINS. -A system of weight measurement in which 7,000 grains equal 1 lb.

GROUND VIBRATION. -A shaking of the ground caused by the elastic wave emanating from a blast. Excessive vibrations may cause damage to structures.

HANGFIRE. -The detonation of an explosive charge at a time after its designed firing time. A source of serious accidents.

HEADING. -A horizontal excavation driven in an underground mine.

HERCUDET. -See gas detonation system.

HERTZ. -A term used to express the frequency of ground vibrations and airblast. One hertz is one cycle per second.

HIGH EXPLOSIVE. -Any product used in blasting which is sensitive to a No. 8 test blasting cap and reacts at a speed faster than that of sound in the explosive medium. A classification used by BATF for explosive storage.

HIGHWALL. -The bench, bluff or ledge on the edge of a surface excavation. This term is most commonly used in coal strip mining.

IGNITACORD. -A cordlike fuse that burns progressively along its length with an external flame at the zone of burning and is used for lighting a series of safety fuses in sequence. Burns with a spitting flame similar to a Fourth-of-July sparkler.

IME. -The Institute of Makers of Explosives. A trade organization dealing with the use of explosives, concerned with safety in manufacture, transportation, storage, handling and use. The IME publishes a series of blasting safety pamphlets.

INITIATION. -The act of detonating a high explosive by means of a cap, a mechanical device, or other means. Also the act of detonating the initiator.

INSTANTANEOUS DETONATOR. -A detonator that contains no delay element.

JET LOADER. -A system for loading AN-FO into small blastholes in which the AN-FO is drawn from a container by the venturi principle and blown into the hole at high velocity through a semiconductive loading hose.

JOINTS. -Planes within a rock mass along which there is no resistance to separation and along which there has been no relative movement of the material on either side. Joints occur in sets, the planes of which may be mutually perpendicular. Joints are often called partings.

JUMBO. -A machine designed to contain two or more mounted drilling units that may or may not be operated independently.

KERF. -A slot cut in a coal or soft rock face by a mechanical cutter to provide a free face for blasting.

LEAD WIRE. -The wire connecting the electrical power source with the leg wires or connecting wires of a blasting circuit. Also called firing line.

LEDC. -Low energy detonating cord, which may be used to initiate nonelectric blasting caps.

LEG WIRES. -Wire connected to the bridge of an electric blasting cap and extending from the waterproof plug. The opposite ends are used to connect the cap into a circuit.

LIFTERS. -The bottom holes in a tunnel or drift round.

LINE DRILLING. -A method of overbreak control in which a series of very closely spaced holes are drilled at the perimeter of the excavation. These holes are not loaded with explosive.

LIQUID OXYGEN EXPLOSIVE. -A high explosive made by soaking cartridges of carbonaceous materials in liquid oxygen. This explosive is rarely used today.

LOADING DENSITY. -An expression of explosive density in terms of pounds of explosive per foot of charge of a specific diameter.

LOADING FACTOR. -See powder factor.

LOADING POLE. -A pole made of nonsparking material, used to push explosive cartridges into a borehole and to break and tightly pack the explosive cartridges into the hole.

LOW EXPLOSIVE. -An explosive in which the speed of reaction is slower than the speed of sound, such as black powder. A classification used by BATF for explosive storage.

LOX. -See liquid oxygen explosive.

MAGAZINE. -A building, structure, or container specially constructed for storing explosives, blasting agents, detonators, or other explosive materials.

MAT. -A covering placed over a shot to hold down flying material; usually made of woven wire cable, rope, or scrap tires.

MAXIMUM FIRING CURRENT. -The highest current (amperage) recommended for the safe and effective performance of an electric blasting cap.

METALLIZED. -Sensitized or energized with finely divided metal flakes, powders, or granules, usually aluminum.

MICHIGAN CUT. -See parallel hole cut.

MICROBALLOONS. -Tiny hollow spheres of glass or plastic which are added to explosive materials to enhance sensitivity by assuring an adequate content of entrapped air.

MILLISECOND. -The unit of measurement of short delay intervals, equal to 1/1000 of a second.

MILLISECOND DELAY CAPS. -Delay detonators that have built-in time delays of various lengths. The interval between the delays at the lower end of the series is usually 25 ms. The interval between delays at the upper end of the series may be 100 to 300 ms.

MINIMUM FIRING CURRENT. -The lowest current (amperage) that will initiate an electric blasting cap within a specified short interval of time.

MISFIRE. -A charge, or part of a charge, which for any reason has failed to fire as planned. All misfires are dangerous.

MONOMETHYLAMINENITRATE. -A compound used to sensitize some water gels.

MS CONNECTOR. -A device used as a delay in a detonating cord circuit connecting one hole in the circuit with another or one row of holes to other rows of holes.

MHSA. -The Mine Safety and Health Administration. An agency under the Department of Labor which enforces health and safety regulations in the mining industry.

MUCKPILE. -A pile of broken rock or dirt that is to be loaded for removal.

MUD CAP. -Referred to also as adobe, bulldoze, blistering, or plaster shot. A charge of explosive fired in contact with the surface of a rock, usually covered with a quantity of mud, wet earth, or similar substance. No borehole is used.

MULTIMETER. -(More properly called blasters' multimeter.) A multipurpose test instrument used to check line voltages, firing circuits, current leakage, stray currents, and other measurements pertinent to electric blasting. Only a meter specifically designated as a blasters' multimeter or blasters' galvanometer should be used to test electric blasting circuits.

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA). -An industry -government association that publishes standards for explosive material and ammonium nitrate.

NITROCARBONITRATE. -A classification once given to a blasting agent by DOT for shipping purposes. This term is now obsolete.

NITROGEN OXIDES. -Poisonous gases created by detonating explosive materials. Excessive nitrogen oxides may be caused by an excessive amount of oxygen in the explosive mixture (excessive oxidizer), or by inefficient detonation.

NITROGLYCERIN (NG). -The explosive oil originally used as the sensitizer in dynamites, represented by the formula $C_3H_5(ONO_2)_3$.

NITROMETHANE. -A liquid compound used as a fuel in two-component (binary) explosives and as rocket fuel.

NITROPROPANE. -A liquid fuel that can be combined with pulverized ammonium nitrate prills to make a dense blasting mixture.

NITROSTARCH. -A solid explosive, similar to nitroglycerin in function, used as the base of "nonheadache" powders.

NONEL. -See shock tube system.

NONELECTRIC DELAY BLASTING CAP. -A detonator with a delay element, capable of being initiated nonelectrically. See shock tube system; gas detonation system; Detaline System.

NO. 8 TEST BLASTING CAP. -See test blasting cap No. 8.

OSHA. -The Occupational Safety and Health Administration. An agency under the Department of Labor which enforces health and safety regulations in the construction industry, including blasting.

OSMRE. -The Office of Surface Mining Reclamation and Enforcement. An agency under the Department of Interior which enforces surface environmental regulations in the coal mining industry.

OVERBREAK. -Excessive breakage of rock beyond the desired excavation limit.

OVERBURDEN. -Worthless material lying on top of a deposit of useful materials. Overburden often refers to dirt or gravel, but can be rock, such as shale over limestone or shale and limestone over coal.

OVERDRIVE. -The act of inducing a velocity higher than the steady state velocity in a powder column by the use of a powerful primer. Overdrive is a temporary phenomenon and the powder quickly assumes its steady state velocity.

OXIDES OF NITROGEN. -See nitrogen oxides.

OXIDIZER. -An ingredient in an explosive or blasting agent which supplies oxygen to combine with the fuel to form gaseous or solid products of detonation. Ammonium nitrate is the most common oxidizer used in commercial explosives.

OXYGEN BALANCE. -A state of equilibrium in a mixture of fuels and oxidizers at which the gaseous products of detonation are predominately carbon dioxide, water vapor (steam), and free nitrogen. A mixture containing excess oxygen has a positive oxygen balance. One with excess fuel has a negative oxygen balance.

PARALLEL CIRCUIT. -A circuit in which two wires, called bus wires, extended from the lead wire. One leg wire from each cap in the circuit is hooked to each of the bus wires.

PARALLEL HOLE CUT. -A group of parallel holes, some of which are loaded with explosives, used to establish a free face in tunnel or heading blasting. One or more of the unloaded holes may be larger than the blastholes. Also called Coromant, Cornish, burn, shatter, or Michigan cut.

PARALLEL SERIES CIRCUIT. -Similar to a parallel circuit, but involving two or more series of electric blasting caps. One end of each series of caps is connected to each of the bus wires. Sometimes called series-in-parallel circuit.

PARTICLE VELOCITY. -A measure of ground vibration. Describes the velocity at which a particle of ground vibrates when excited by a seismic wave.

PATTERN. -A plan of holes laid out on a face or bench which are to be drilled for blasting. Burden and spacing dimensions are usually expressed in feet.

PELLET POWDER. -Black powder pressed into 2-in-long, 1¼-in to 2-in diameter cylindrical pellets.

PENTAERYTHRITOLTETRANITRATE (PETN). -A military explosive compound used as the core load of detonating cord and the base charge of blasting caps.

PENTOLITE. -A mixture of PETN and TNT which, when cast, is used as a cast primer.

PERMISSIBLE. -A machine, material, apparatus, or device that has been investigated, tested and approved by the Bureau of Mines or MSHA, and is maintained in permissible condition (MSHA).

PERMISSIBLE BLASTING. -Blasting according to MSHA regulations for underground coal mines or other gassy underground mines.

PERMISSIBLE EXPLOSIVES. -Explosives that have been approved by MSHA for use in underground coal mines or other gassy mines.

PETN. -See pentaerythritoltetranitrate.

PLACARDS. -Signs placed on vehicles transporting hazardous materials, including explosives, indicating the nature of the cargo.

PLASTER SHOT. -See mud cap.

PNEUMATIC LOADER. -One of a variety of machines, powered by compressed air, used to load blasting agents or cartridged water gels.

POWDER. -Any solid explosive.

POWDER CHEST. -A substantial, nonconductive portable container equipped with a lid and used at blasting sites for temporary storage of explosives.

POWDER FACTOR. -A ratio between the amount of powder loaded and the amount of rock broken, usually expressed as pounds per ton or pounds per cubic yard. In some cases, the reciprocals of these terms are used.

PREBLAST SURVEY. -A documentation of the existing condition of a structure. The survey is used to determine whether subsequent blasting causes damage to the structure.

PREMATURE. -A charge that detonates before it is intended. Prematures can be hazardous.

PRESHEARING. -See presplitting.

PRESPLITTING. -A form of controlled blasting in which decoupled charges are fired in closely spaced holes at the perimeter of the excavation. A presplit blast is fired before the main blast. Also called preshearing.

PRESSURE VESSEL. -A system for loading AN-FO into small diameter blastholes. The AN-FO is contained in a sealed vessel, to which air pressure is applied, forcing the AN-FO through a semiconductive hose and into the blasthole. Also known as a pressure pot.

PRILL. -In blasting, a small porous sphere of ammonium nitrate capable of absorbing more than 6 pct. by weight of fuel oil. Blasting prills have a bulk density of 0.80 to 0.85 g/cu cm.

PRIMARY BLAST. -The main blast executed to sustain production.

PRIMARY EXPLOSIVE. -An explosive or explosive mixture, sensitive to spark, flame, impact or friction, used in a detonator to initiate the explosion.

PRIMER. -A unit, package, or cartridge of cap sensitive explosive used to initiate other explosives or blasting agents and which contains a detonator (MSHA).

PROPAGATION. -The detonation of explosive charges by an impulse from a nearby explosive charge.

PROPAGATION BLASTING. -The use of closely spaced, sensitive charges. The shock from the first charge propagates through the ground, setting off the adjacent charge, and so on. Only one detonator is required. Primarily used for ditching in damp ground.

PROPELLANT EXPLOSIVE. -An explosive that normally deflagrates and is used for propulsion.

PULL. -The quantity of rock or length of advance excavated by a blast round.

RADIOFREQUENCY ENERGY. -Electrical energy traveling through the air as radio or electromagnetic waves. Under ideal conditions, this energy can fire an electric blasting cap. IME Pamphlet No. 20 recommends safe distances from transmitters to electric blasting caps.

RADIOFREQUENCY TRANSMITTER. -An electric device, such as a stationary or mobile radio transmitting station, which transmits a radiofrequency wave.

RDX. -Cyclotrimethylenetrinitramine, an explosive substance used in the manufacture of compositions B, C-3 and C-4. Composition B is useful as a cast primer.

RELIEVERS. -In a heading round, holes adjacent to the cut holes, used to expand the opening made by the cut holes.

RIB HOLES. -The holes at the sides of a tunnel or drift round, which determine the width of the opening.

RIP RAP. -Coarse rocks used for river bank or dam stabilization to reduce erosion by water flow.

ROTATIONAL FIRING. -A delay blasting system in which each charge successively displaces its burden into a void created by an explosive detonated on an earlier delay period.

ROUND. -A group or set of blastholes required to produce a unit of advance in underground headings or tunnels.

SAFETY FUSE. -A core of potassium nitrate black powder, enclosed in a covering of textile and waterproofing, which is used to initiate a blasting cap or a black powder charge. Safety fuse burns at a continuous, uniform rate.

SCALED DISTANCE. -A ratio used to predict ground vibrations. As commonly used in blasting, scaled distance equals the distance from the blast to the point of concern, in feet, divided by the square root of the charge weight of explosive per delay, in pounds. Normally, when using the equation, the delay period must be at least 9 ms.

SECONDARY BLASTING. -Using explosives to break boulders or high bottom resulting from the primary blast.

SEISMOGRAPH. -An instrument that measures and may supply a permanent record of earthborne vibrations induced by earthquakes or blasting.

SEMICONDUCTIVE HOSE. -A hose, used for pneumatic loading of AN-FO, which has a minimum electrical resistance of 1,000 ohms/ft and 10,000 ohms total resistance and a maximum total resistance of 2,000,000 ohms.

SENSITIVENESS. -A measure of an explosive's ability to propagate a detonation.

SENSITIVITY. -A measure of an explosive's susceptibility to detonation upon receiving an external impulse such as impact, shock, flame, or friction.

SENSITIZER. -An ingredient used in explosive compounds to promote greater ease in initiation or propagation of the detonation reaction.

SEQUENTIAL BLASTING MACHINE. -A series of condenser discharge blasting machines in a single unit which can be activated at various accurately timed intervals following the application of electrical current.

SERIES CIRCUIT. -A circuit of electric blasting caps in which each leg wire of a cap is connected to a leg wire from the adjacent caps so that the electrical current follows a single path through the entire circuit.

SERIES-IN-PARALLEL CIRCUIT. -See parallel series circuit.

SHATTER CUT. -See parallel hole cut.

SHELF LIFE. -The length of time for which an explosive can be stored without losing its efficient performance characteristics.

SHOCK ENERGY. -The shattering force of an explosive caused by the detonation wave.

SHOCK TUBE SYSTEM. -A system for initiating caps in which the energy is transmitted to the cap by means of a shock wave inside a hollow plastic tube.

SHOCK WAVE. -A pressure pulse that propagates at supersonic velocity.

SHOT. -See blast.

SHOT FIRER. -Also referred to as the shooter. The person who actually fires a blast. A powderman, on the other hand, may charge or load blastholes with explosives but may not fire the blast.

SHUNT. -A piece of metal or metal foil which short circuits the ends of cap leg wires to prevent stray currents from causing accidental detonation of the cap.

SILVER CHLORIDE CELL. -A low-current cell used in a blasting galvanometer and other devices used to measure continuity in electric blasting caps and circuits.

SLURRY. -An aqueous solution of ammonium nitrate, sensitized with a fuel, thickened, and crosslinked to provide a gelatinous consistency. Sometimes called a water gel. DOT may classify a slurry as a Class A explosive, a Class B explosive, or a blasting agent. An explosive or blasting agent containing substantial portions of water (MSHA). See emulsion; water gel.

SMOOTH BLASTING. -A method of controlled blasting, used underground, in which a series of closely spaced holes is drilled at the perimeter, loaded with decoupled charges, and fired on the highest delay period of the blast round.

SNAKE HOLE. -A borehole drilled slightly downward from horizontal into the floor of a quarry face. Also, a hole drilled under a boulder.

SODIUM NITRATE. -An oxidizer used in dynamites and sometimes in blasting agents.

SPACING. -The distance between boreholes or charges in a row, measured perpendicular to the burden and parallel to the free face of expected rock movement.

SPECIFIC GRAVITY. -The ratio of the weight of a given volume of any substance to the weight of an equal volume of water.

SPLITTER CORD. -See Ignitacord.

SPRINGING. -See chambering.

SQUARE PATTERN. -A pattern of blastholes in which the holes in succeeding rows are drilled directly behind the holes in the front row. In a truly square pattern the burden and spacing are equal.

SQUIB. -A fire device that burns with a flash. Used to ignite black powder or pellet powder.

STABILITY. -The ability of an explosive material to maintain its physical and chemical properties over a period of time in storage.

STAGGERED PATTERN. -A pattern of blastholes in which holes in each row are drilled between the holes in the preceding row.

STATIC ELECTRICITY. -Electrical energy stored on a person or object in a manner similar to that of a capacitor. Static electricity may be discharged into electrical initiators, thereby detonating them.

STEADY STATE VELOCITY. -The characteristic velocity at which a specific velocity, under specific conditions, in a given charge diameter, will detonate.

STEMMING. -The inert material, such as drill cuttings, used in the collar portion (or elsewhere) of a blasthole to confine the gaseous products of detonation. Also, the length of blasthole left uncharged.

STICK COUNT. -See cartridge count.

STRAY CURRENT. -Current flowing outside its normal conductor. A result of defective insulation, it may come from electrical equipment, electrified fences, electric railways, or similar items. Flow is facilitated by conductive paths such as pipelines and wet ground or other wet materials. Galvanic action of two dissimilar metals, in contact or connected by a conductor, may cause stray current.

STRENGTH. -A property of an explosive described in various terms such as cartridge or weight strength, seismic strength, shock or bubble energy, crater strength, ballistic mortar strength, etc. Not a well-defined property. Used to express an explosive's capacity to do work.

STRING LOADING. -The procedure of loading cartridges end to end in a borehole without deforming them. Used mainly in controlled blasting and permissible blasting.

SUBDRILL. -To drill blastholes beyond the planned grade lines or below floor level to insure breakage to the planned grade or floor level.

SUBSONIC. -Slower than the speed of sound.

SUPERSONIC. -Faster than the speed of sound.

SWELL FACTOR. -The ratio of the volume of a material in its solid state to that when broken. May also be expressed as the reciprocal of this number.

SYMPATHETIC PROPAGATION (SYMPATHETIC DETONATION). - Detonation of an explosive material by means of an impulse from another detonation through air, earth or water.

TAMPING. -The process of compressing the stemming or explosive in a blasthole. Sometimes used synonymously with stemming.

TAMPING BAG. -A cylindrical bag containing stemming material, used to confine explosive charges in boreholes.

TAMPING POLE. -See loading pole.

TEST BLASTING CAP NO. 8. -A detonator containing 0.40 to 0.45 g of PETN base charge at a specific gravity of 1.4 g/cu cm, and primed with standard weights of primer, depending on the manufacturer.

TOE. -The burden or distance between the bottom of a borehole and the vertical free face of a bench in an excavation. Also the rock left unbroken at the foot of a quarry blast.

TRANSIENT VELOCITY. -A velocity, different from the steady state velocity, which a primer imparts to a column of powder.

TRINITROTOLUENE (TNT). -A military explosive compound used industrially as a sensitizer for slurries and as an ingredient in pentolite and composition B. Once used as a free-running pelletized powder.

TRUNKLINE. -A detonating cord line used to connect the downlines or other detonating cord lines in a blast pattern. Usually runs along each row of blastholes.

TUNNEL. -A horizontal underground passage.

TWO-COMPONENT EXPLOSIVE. -See binary explosive.

UNCONFINED DETONATION VELOCITY. -The detonation velocity of an explosive material not confined by a borehole or other confined medium.

V-CUT. -A cut employing several pairs of angled holes, meeting at the bottoms, used to create free faces for the rest of the blast round.

VELOCITY. -The rate at which the detonation wave travels through an explosive. May be measured confined or unconfined. Manufacturer's data are sometimes measured with explosives confined in a steel pipe.

VENTURI LOADER. -See jet loader.

VOLUME STRENGTH. -See cartridge strength or bulk strength.

WATER GEL. -An aqueous solution of ammonium nitrate, sensitized with a fuel, thickened, and crosslinked to provide a gelatinous consistency. Also called a slurry. May be an explosive or a blasting agent.

WATER RESISTANCE. -A qualitative measure of the ability of an explosive or blasting agent to withstand exposure of water without becoming deteriorated or desensitized.

WATER STEMMING BAGS. -Plastic bags containing a self-sealing device, which are filled with water. Classified as a permissible stemming device by MSHA.

WEIGHT STRENGTH. -A rating that compares the strength of a given weight of explosive with an equivalent weight of straight nitroglycerin dynamite, or other explosive standard, expressed as a percentage.

APPENDIX 'D'

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