

CONTENTS

<i>Symbols used</i>	16
1. The mechanics of breakage	18
2. Calculation of the charge. General part	28
2.1. The law of conformity	29
2.2. Older formulas	30
2.3. Basic principles regarding loosening of the rock	31
2.4. Formulas for a single drill hole	35
a. <i>Bottom charge, concentrated</i>	35
b. <i>Column charge</i>	36
c. <i>Total charge</i>	37
d. <i>The distribution of the charge</i>	38
2.5. Formula for a straight bench with several drill holes	41
2.6. Degree of fixation and slope of the holes	41
2.7. The rock constant <i>c</i>	43
2.8. Diameter of drill holes, degree of packing	44
2.9. Hole spacing	45
2.10. Maximum burden	45
2.11. Throw	46
2.12. Swelling	46
2.13. Fragmentation	55
2.14. Rock blasting with nuclear explosives	55
2.15. Summary of formulas for bench blasting and stoping	58
2.16. The formulas expressed in diagrams	59
2.17. Problems	64
3. Calculation of the charge. Practical application	69
3.1. Some simplified connections	69
3.2. Maximum and minimum charge in single-row bench blasting	71
a. <i>Ordinary benches, $K \geq 1.8 V$</i>	71
b. <i>Low benches, $K < 1.8 V$</i>	71
c. <i>Various rock factors</i>	74
3.3. Practical application	74
a. <i>Correction for deviations in the drilling</i>	74
b. <i>Need for swell in multiple-row blasting</i>	76
c. <i>Some tables for practical application</i>	78
d. <i>Blasting in sedimentary rock</i>	80
3.4. Distribution of the charge	83
3.5. Problems	86

4.	Loading of drill holes (by C. H. Johansson and S. Ljungberg)	87
4.1.	Simple loading methods	87
	a. <i>Rod tamping</i>	87
	b. <i>Long rigid cartridges</i>	88
	c. <i>Blowing in the cartridges with compressed air</i>	88
	d. <i>Loading with sticks</i>	89
	e. <i>Charges for smooth blasting</i>	89
4.2.	The pneumatic cartridge loader	91
	a. <i>Introduction</i>	91
	b. <i>The design and function of the loader</i>	92
	c. <i>Safety considerations</i>	98
	d. <i>Practical experience</i>	100
4.3.	The pressure water loader	101
4.4.	Loading AN-mixtures and other powder explosives	102
	a. <i>Different types of powder loaders</i>	103
	b. <i>Directions for the operation of the powder loaders</i>	106
	c. <i>Practical experience</i>	107
4.5.	Degree of packing in different loading procedures	109
	a. <i>Shape and volume of drill holes</i>	109
	b. <i>Loading with tamping pole</i>	111
	c. <i>Pre-arranged cartridges</i>	113
	d. <i>The pneumatic cartridge loader</i>	114
4.6.	Problems	116
5.	Bench blasting with ammonium nitrate explosives	
5.1.	Conditions	117
5.2.	Various alternatives	119
5.3.	Calculation of the costs	121
5.4.	Analysis of results	131
5.5.	Summary	137
5.6.	Problems	137
6.	Short delay blasting. Multiple-row rounds	139
6.1.	Ignition	139
	a. <i>Blasting machines</i>	139
	b. <i>Electric MS-detonators</i>	142
	c. <i>Checking the electric system</i>	144
	d. <i>Detonating fuse</i>	142
6.2.	Delay interval and fragmentation	
6.3.	Drilling and ignition patterns	150
	a. <i>Slope of the holes</i>	
	b. <i>Ignition sequence in a row</i>	152
	c. <i>Multiple-row rounds</i>	152
	d. <i>Free faces</i>	159
	e. <i>Rounds including opening cut</i>	160
	f. <i>Improved fragmentation</i>	161
6.4.	Bottom bench in tunnels. Canals	162
6.5.	Low bench blasting	164

6.6.	Road construction	
6.7.	Foundation of buildings.	
6.8.	Trenching	170
6.9.	Safety measures in electric ignition	173
	a. <i>Leakage of current</i>	173
	b. <i>Static electricity</i>	174
	c. <i>Lightning</i>	174
	d. <i>Power lines</i>	176
	e. <i>Radio frequencies</i>	176
6.10.	Planning the work	177
6.11.	Problems	178
Tunnel blasting		180
7.1.	Breakage in the case of free burden.	180
7.2.	Drilling precision.	182
7.3.	Calculation of the charge for small angles of breakage.	186
7.4.	Consumption of explosive	188
7.5.	Different types of cut.	189
	<i>Fan cut</i>	189
	<i>Plough cut</i>	190
	<i>Instantaneous cuts</i>	193
	<i>Parallel hole cuts</i>	195
7.6.	Advance per round.	195
7.7.	Choice of section	200
7.8.	Construction of stoping and ignition patterns	201
7.9.	The rhythm of the driving.	205
7.10.	Drilling and ignition patterns	206
7.11.	Problems	229
8.	Tunnel blasting with parallel hole cuts	230
8.1.	Basic relations	232
	a. <i>Concentration of charge</i>	232
	b. <i>Clean blasting and plastic deformation.</i>	233
	c. <i>Flash-over</i>	234
	d. <i>The effect of the explosive</i>	235
	e. <i>Influence of the diameter of the charged holes</i>	236
	f. <i>Influence of the rock</i>	236
	g. <i>Influence of the ignition sequence</i>	237
	h. <i>Deviation in drilling</i>	238
	i. <i>Advance per round</i>	239
	j. <i>Throw, fragmentation</i>	242
8.2.	Different types of parallel hole cuts.	243
	a. <i>Cylinder cuts</i>	244
	b. <i>Burn cuts</i>	249
	c. <i>Crater cuts</i>	251
8.3.	Results from driving with parallel hole cuts	251
8.4.	Conclusions	256
8.5.	Problems	257

9.	Ground vibrations	258
9.1.	Apparatus for recording ground vibrations	259
9.2.	Reading the vibrograms	265
9.3.	Character of the ground vibrations	267
9.4.	Damage	269
	a. <i>Compression-elongation</i>	271
	b. <i>Shearing</i>	273
	c. <i>Bending</i>	273
	d. <i>Local effects</i>	273
	e. <i>Vibration energy</i>	275
	f. <i>Subjective estimate</i>	276
	g. <i>Discussion</i>	277
9.5.	Reduction of ground vibrations	281
9.6.	Planning blasting operations	285
9.7.	Practical directions	288
9.8.	Problems	295
10.	Smooth blasting and presplitting	296
10.1.	Formation of cracks	297
10.2.	Reduction of cracking	301
10.3.	Burden and spacing	302
10.4.	Ignition	303
10.5.	Presplitting	304
10.6.	Practical directions	308
10.7.	Results from smooth blasting and presplitting	312
10.8.	Problems	320
11	Underwater blasting and blasting through overburden	322
11.1.	Calculation of the charge	322
	a. <i>Breakage</i>	323
	b. <i>Deviation in drilling</i>	326
	c. <i>Swelling</i>	326
	d. <i>Fragmentation</i>	329
	e. <i>Effect of faulty holes</i>	330
11.2.	Drilling pattern	333
11.3.	Explosive	339
11.4.	Loading of holes	341
11.5.	Electric ignition and control	343
11.6.	Ignition through flash-over	345
11.7.	Ground vibration and shock waves	347
11.8.	Reduction of pressure and impulse in the water shock waves	350
	a. <i>Reduction of pressure through the choice and placing of the explosive</i>	350
	b. <i>Reduction of pressure by an air-bubble curtain</i>	352
	c. <i>Reduction of the impulse</i>	353
11.9.	Various types of objects	356
11.10.	Practical directions	356
11.11.	Questions put by a contractor before the planning of the job	360

12. Non electric blasting	365
12.1. The Nonel system	365
12.2. The Nonel GT detonator	365
12.3. The connectors and starters	367
12.4. The connecting of a round	369
a. <i>Initiating</i>	369
b. <i>The ignition pattern</i>	369
c. <i>Half delays</i>	371
d. <i>Duplicated connection</i>	372
e. <i>Trench blasting</i>	374
f. <i>Tunnel blasting</i>	374
13. The use of underground space	375
<i>Bibliography</i>	398
<i>Appendix 1. Notes on the problems</i>	408
<i>Appendix 2. List of words: Spanish-English-Swedish</i>	417
<i>Appendix 3. Table of units: English-Metric</i>	437

