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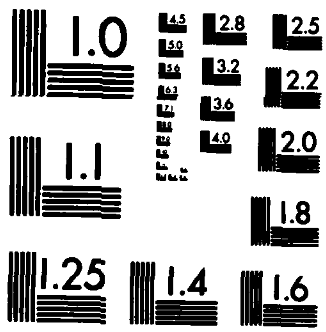

OPY RESOLUTION TEST CHART

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FOREIGN TECHNOLOGY DIVISION

MINING OPERATIONS

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EDITED TRANSLATION

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graghics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

Chapter 1.

MINING OPERATIONS

General Aspects

Rock Hardness

1. **Hardness coefficients.** Rock hardness must be determined by the hardness coefficient that characterizes relative hardness of each rock and is designated by the letter f.

Категория. 1	Степень крепости. 2	3 Породы.	f
I.	4 В высшей степени крепкие породы.	Наиболее крепкие, плотные и вязкие кварциты и базальты. Исключительные по крепости другие породы. 14	20
II.	5 Очень крепкие породы.	Очень крепкие гранитовые породы. Кварцевый порфир, очень крепкий гранит, кремнистый сланец, менее крепкие, нежели указанные выше, кварциты. Самые крепкие песчаники и известняки. 15	15
III.	6 Крепкие породы.	Гранит (плотный) и гранитовые породы. Очень крепкие песчаники и известняки. Кварцевые рудные жилы. Крепкий конгломерат. Очень крепкие железные руды. 16	10
III a.	»	Известняки (крепкие). Некрепкий гранит. Крепкие песчаники. Крепкий мрамор, доломит. Колчеданы. 17	8
IV.	7 Довольно крепкие породы	Обыкновенный песчаник. Железные руды. 12	6
IV a.	»	Песчанистые сланцы. Сланцеватые песчаники. 19	5
V.	8 Средние породы.	Крепкий глинистый сланец. Некрепкий песчаник и известняк, мягкий конгломерат. 20	4
V a.	»	Разнообразные сланцы (некрепкие). Плотный мергель. 21	3
VI.	9 Довольно мягкие породы.	Мягкий сланец, очень мягкий известняк, мел, каменная соль, гипс. Мерзлый грунт, антрацит. Обыкновенный мергель. Разрушенный песчаник, цементированная галька и хрящ, — каменистый грунт. 22	2
VI a.	»	Щебенистый грунт. Разрушенный сланец, слежавшаяся галька и щебень, крепкий каменный уголь, отвердевшая глина. 23	1.5
VII	10 Мягкие породы	Глина (плотная). Мягкий каменный уголь, крепкий нанос, — глинистый грунт. 24	1.0
VII a	»	Легкая песчанистая глина, лесс, гравий. 25	0.8
VIII	11 Землистые породы	Растительная земля. Торф. Легкий суглинок, сырой песок. 26	0.6
IX.	12 Сыпучие породы	Песок, осыпи, мелкий гравий, насыпная земля, добытый уголь. 27	0.5
X	13 Плывучие породы.	Плывуны, болотистый грунт, разжиженный лесс и др. разжиженные грунты. 28	0.3

Key: (1) categories; (2) degree of hardness; (3) rocks; (4) extremely hard rocks; (5) very hard rocks; (6) hard rocks; (7) fairly hard rocks; (8) medium rocks; (9) rather soft rocks; (10) soft rocks; (11) earth rocks; (12) loose rocks; (13) quick ground; (14)most hard, dense and viscous quarzites and basalts. Other rocks of extreme hardness; (15) very hard granite rocks. Quartz-porphyry, very hard granite, flinty slate, and quartzite that are less hard than the above. Hardest sandstones and limestones; (16) granite (dense) and granite rocks. Very hard sanstones and lime stones. Quartz ore veins. Hard conglomerate. Very hard iron ores; (17) Limestones (hard). Nonhard granite. Hard limestones. Hard marble, dolomite. Pyrites; (18) common sandstone. Iron ores; (19) sandy shales. Schistose sandstones; (20) hard clay shale. Nonhard sandstone and limestone, soft conglomerate; (21) various slates (nonhard). Dense marl; (22) soft slate, very soft limestone, chalk, rock salt, gypsum. Frozen soil, anthracite. Common marl. Destroyed sandstone. Cemented pebble and gravel - rocky soil; (23) rubble soil. Destroyed slatecaked pebble and rock debris, hard coal, hardened clay; (24) Clay (dense). Soft coal. Hard alluviation 0 clay soil; (25) light sandy clay, loess, gravel; (26) sod. Peat. Light loam. Wet sand; (27) sand, talus, small gravel, filled soil, extracted coal; (28) quicksands, marshy ground, diluted loess and other diluted soils.

Comment 1. Each rock should be related to a certain class not only by its name, but also by its physical condition comparing its hardness with that of other rocks which are listed in the table. Rocks that are weathered, destroyed, broken separately, deformed by dislocation, and close to surface must be related to lower categories that rocks of the same name, listed in the Table which, generaly speaking, means rocks in dense condition.

Comment 2. The above coefficient of hardness should be considered as characterizing the relative hardness of the rock in all variety of relations important in mining, namely: a) in relation to mining through manual operations; b) drilling capacity both in blast-hole drilling and in deep drilling; c) explosiveness by means of explosives; d) stability at caving; e) pressure applied to a support, etc.

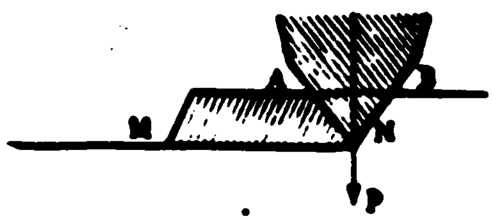
However, one must keep in mind that numbers in the Table relate to the entire group of rocks (for example, slates, quartzites, limestomes, etc.), but not to their separate variations. Therefore, determination of f in some particular cases must be treated very cautously and this value can be not the same in various respects.

An example. Let us imagine that the given granite, while being a strong one, is broken by the strong jointing ($f = 10$). This is not important for blast-hole drilling, and f must be taken as it is given. However, it is evident that such granite easily breaks into fractions upon explosing and it requires little explosive material. Therefore, in this case less f is needed, for example 8 or 6, depending on circumstances.

Foundation. The concept of rock hardness, presented in this paragraph, is the cardinal point on which the whole "Fixed Status" is based, and the lack of it makes impossibke existance of any general standards but results in a series of separate, infinitely variable cases. Therefore, it deserves thorough examination.

Hardness of a rock, as well as of any other material, is its resistance to external stresses. In each particular case, this resistance is stipulated by a certain combination of elementary resistances against stretching, compression, shear that is as variable as the method of application of stresses.

Imagine, for example, that we put the drill blade on the rock and struck it with the hammer. Then, under the effect of the force P, the drill plunged to a certain depth into the rock, crushing it, on one side, immediately under the blade throughout the area AB, and on the other side, it splits off a piece throughout the area MN. Thus, the general rock resistance to the drill consists of the resistance to crushing and, partially, of the resistance of splitting off. If in each given case we know the magnitude and ratio of developing stresses, the task would be a common one and would be reduced to elementary resistances. But in mining nobody has investigated what kind of resistances occur while operating with a pike, a crow-bar, during drilling, exploding, etc., and all known attempts to determine them in drilling and rock pressure have been insufficient. Therefore we will try to show that even if one does not know the distribution of stresses in the rock, it is still possible to establish approximately the relative resistance of different rocks and that this resistance is the same for any rock independent of any particular relation.



Фиг. 1.

Fig. 1.

Imagine that a certain force P is applied to the rock. Depending on its nature, magnitude and method, it produces various stresses in the rock - compressing, stretching, bending, etc., so that

$$P = F (d, z, s, b \dots)$$

where d - stress from compression, z - that from stretching, s - from shear, b - from bending, etc. F means certain functional dependence.

However, each of the stresses must be directly proportional to the applied force, and if this latter increases, let us say, by two times, all compressing, stretching and other stresses will also increase by two times independent of how intricate could be distribution of various stresses. And this can occur only in the case if function F is such that all D, z, s ... are comprised in the form of an algebraic sum and of first degree only. Hence, we can write

$$P = Ad + A_1z + A_2s + A_3b + \ldots \qquad (1)$$

where A, A_1, A_2, A_3 are some simple or complex algebraic expressions independent of d, z, s ... We will call then the "action conditions". The stress values cannot multiply, divide or be included in any degree but the first. Indeed, let imagine that this condition is eliminated. Imagine that

$$P = dz$$

Then, when ρ increases by two times, d and z cannot increase by two times each, otherwise the second part would increase by four times thus disrupting the equality. It is also impossible that A, A_1, A_2, A_3 depend on d,z,s,b ...

Hence, all stresses d, z, s, b ... must be proportional to each other because they are all proportional to P. i.e. they can all be expressed through one of them, for example, d

$$z = k_1d; \; s = k_2d; \; b = k_3d \ldots$$

where k_1, k_2, k_3 are certain coefficients of proportionality. In such case we can write

$$P = Ad + A_1k_1d + A_2k_2d + A_3k_3d + \ldots \qquad (II)$$

Or

$$P = d(A + A_1k_1 + A_2k_2 + A_3k_3 + \ldots)$$

Designating the expression in brackets through K, we obtain

$$P = Kd \qquad (III)$$

Thus, at any, even the most intricate distribution of various stresses in the rock, the active force should always be proportional to some stress, selected arbitrary.

If we increase the force P, the moment will occur when some of the d, z, s, b ... stresses (expression 1) reaches the maximum of the rock resistance and the rock will begin to collapse. Generally speaking, this breaking point should not be necessarily reached at the same time by all stresses, but this situation provides for the most advantageous utilization of the force P and the most complete rock breaking. This only requires corresponding selection of conditions of application of the force P to the rock, i.e. A, A_1, A_2, A_3 ... coefficients or K (which means the same).

Let us give an example. When a drill is applied to the rock (see above), the impact force is divided into the vertical crushing force and the horizontal splitting force. If the former is sufficient for crushing the rock under the blade thrpughout AB, then it is not necessarily required that at that moment the second force is capable of splitting off the rock thrpughout MN. But we can place the drill in such a distance from the edge (value MN) that makes this possible. Thus, this will be the most advantageous case, the greatest breaking because if MN is less than this - splitting off will not occur, and if MN is less - a smaller piece than desired will be splitted off. This is an instinctive goal of any worker during his operations.

Thus, the most advantageous and, so to speak, normal case is when the conditions of an action upon the rock are such that all stresses reach simultaneously the rock ultimate strength.

Now let us keep the previous conditions of action, i.e. the previous method of application of the force P, previous drill taper angle, previous AB crusing area and MN splitting-off area, etc. Then all A, A_1, A_2 ..., and hence K will remain unchanged, and the expression (III) will still be valid. Imagine that the rock hardness has changed, for example, increased. Then if all time resistances increase by the same magnitude, the breaking point would be reached simultaneously by all stresses with the force P that is higher by the same magnitude.

Imagine, for example, that in the given case the resistance to crushing became twice as high. Then the rock under the blade will break at twice as high force P. At the same time, the splitting-off stresses will also increase by two times ans if in the new rock the resistance to splitting-off is also twice as high than before, the splitting-off throughout MN will occur at the same moment. Thus, the new rock requires as much greater force for its breaking, as much its time resistances are greater. Therefore it is harder than the other one by as much as greater is any of its resistances. Then, all rocks can be arranges into a series by their hardness in accordance with the selected time resistance, and eventually we can write

$$P_m = K_m k$$

where P_m designates the rock breaking force, K_m- an expression that characterizes the given conditions of action, and k_1 - the rock time resistance selected by us[1].

[1] Do not confuse the above k_3 (time resistance) with k_1, k_2, k_3 coefficients of proportionality in the expression II.

If another method of rock breaking is used, for example, explosion instead of drilling, the conditions of action A, A_1, A_2 ... and, hence, K becomes different, but all above considerations remain valid, and two different rocks will require forces for their breaking that are again proportional to k_3 or to any other selected stress

$$P_n = K_n k_3$$

Thus, as much one rock is harder than another in drilling, as much harder it must be in explosion, drilling, fastening, etc. In all these respects, the rocks are arranged into the same series.

However, in reality this does not happen. Time resistances of different rocks are not proportional to each other. This is true that the harder is the rock, the greater are all its resistances: to compression, streatching, shear, etc., but not in identical amount of times. Therefore, K_m and K_n values, selected on the concept of simultaneous acieving the breaking point by all stresses, will not be quite the same for different rocks, and our previous concept only as much as the time resistances in various relations are close to proportionality between each other.

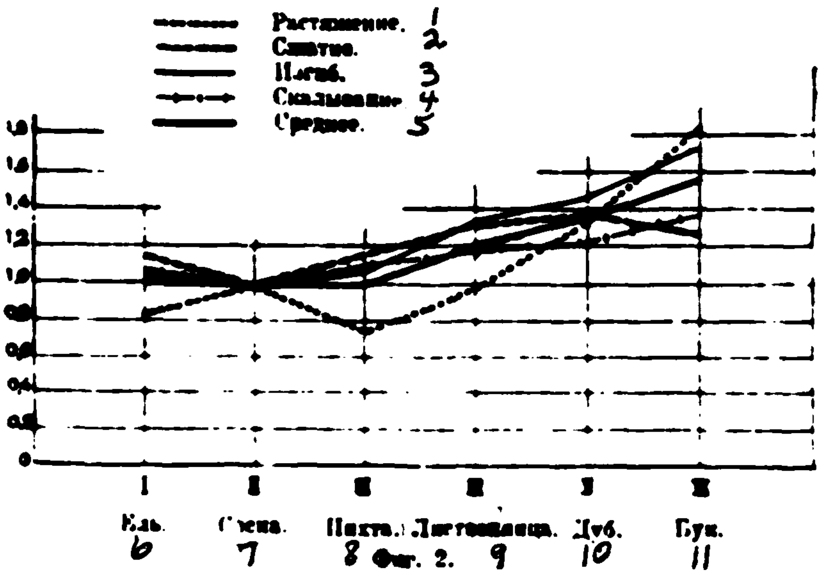
Imagine that in the given example the resistance to crushing increased by two times, and that to splitting-off - by three times. Then, if the force P increases by two times, rock crushing under the blade will take place, but splitting-off will not. We will have to reduce MN by 1.5 times. The conditions of action will be somewhat changed, K will obtain a different value, and the destroyed volume will not be the same any more. The identical breaking will require the force that is proportional to neither compression, nor splitting-off, but to some mean value. Now we have to determine the magnitude of the deviations obtained.

Since our considerations are can be applied similarly to any material but to rock only, let us take wood for which there are good observations carried out over the same sample by the same person (Tethmayer); moreover, they will be needed in future ("Fastening").

Порода дерева. 1	Растяжение. 8		Сжатие. 9		Скалывание. 10		Изгиб. 11		Среднее отношение. 14
	Килог. 12	Относ. 13	Килог. 12	Относ. 13	Килог. 12	Относ. 13	Килог. 12	Относ. 13	
Ель 2	602	0.83	276	1.12	63	1.03	435	1.06	1,01
Сосна 3	720	1.00	246	1.00	61	1.00	409	1.00	1,00
Пихта 4	533	0.74	283	1.15	67	1.10	439	1.07	1.02
Лиственница 5	710	0.99	321	1.32	72	1.18	542	1.33	1.21
Дуб 6	964	1.34	343	1.39	75	1.23	601	1.47	1.36
Бук 7	1340	1.86	320	1.30	85	1.39	720	1.75	1.58

Time resistance in kilograms per square centimeter

Key: (1) wood species; (2) spruce; (3) pine tree; (4) fir; (5) larch; (6) oak; (7) beech; (8) stretching; (9)compression; (10) splitting-off; (11) bending; (12) kilograms; (13) relation; (14) mean ratio.



Фиг. 2.

Key: (1) stretcing; (2) compression; (3) bending; (4) splitting-off; (5) mean; (6) spruce; (7) pine tree; (8) fir; (9) larch; (10) oak; (11) beech.

These data indicate that there is no real strict proportionality between various types of time resistances and that, for example, the stretching resistance in a pine tree is greater than in a spruce or a fir, and that the other types of resistance, on the contrary, are smaller. However, the same data indicate that in general the resistances, especially resistances to compression, splitting-off and bending, can be presented as one group where only the stretching resistance shows substantial deviation, but even this resistance gives the greatest deviation from the mean one (fir) of only 26 percent. If we take into consideration that the more various resistances take place in each given case, the close will the result be to the mean value, and if we remember that in designing the building structures, the reserve is taken by 8, 10 times and only seldom - by 4 times that, if compared, makes our error insignificant, than it becomes clear that we can consider approximately that if some rock is harder than another by several times in a certain relation, for example, in drilling, it will be by the same magnitude harder in any other relation, for example, in explosion, in relation to pressure on the support, etc. The numbers that express the rock relative hardness are " coefficients of hardness", and their most important feature is in the fact that they make it possible to compare rocks not knowing what kinds of stresses and how are they induced. Also, the accuracy of their calculations should not be worse than usual construction calculations with the mentioned enormous hardness reserve.

Various methods can be applied for determination of coefficients of hardness. It is clear from the above information that values of some temporary resistance can be used for this purpose, or even better - mean values from various temporary resistances. The amount of work spent at various mining operations can serve this purpose, as well as the amount of required explosives, pressure resulting from a certain rock, etc.

Let us summarise various data.

(a) Temporary resistance to compression. On the basis of various data, let us select typical rocks and establish values of their resistance to compression (see Table on p. 9).

Unfortunately, there are data only for rocks that are used as construction material. However, there are no data for common mining rocks. Even for coal, we managed to find just a very short mentioning in the report of the Prussian Commission on Collapses, which says that coal resistance of (hard) seam Sattel in the mine Erbreich is 198.5 kg. per square cm, and that in the worst case, coal can sustain 75 kg. (Gorniy zhyrnal, 1903, vol. 8, p. 173).

If the coefficient of hardness of an average granite is taken as 10 K_d = 1000 kg.), then each unit of hardness corresponds to 100 kg. per square cm of temporary resistance. For f, values indicated in the last column are obtained.

(b) Working hours for drilling out one cubic centimeter of a blast-hole during manual drilling. Various data are presented further in Chapter 5, item 128.

Comment of Scientific Technical Council

Item 1 on p. 3. A concept that "each stress must be directly proportional to the active force" is wrong because in mining operations mainly there are bodies that are not regulated by the linear Hooke's law, but by the power law (for example, all rocks, concrete, bricks, cast iron), and if there are bodies regulated by the Hooke's law, they are loaded beyond the ultimate elasticity where direct proportionality cannot be involved. The presentation of the sum of internal stresses, balancing the external force P, described in the right part of the equality I,according to its structure even very conditionally cannot be treated as correct neither by its essence not from the point of view of contemporary hypotheses on hardness and causes of body breaking. Therefore, it is not possible to develop such a comprehensive function that it would be able to desctibe various methods of manifestation of this force P applied either instantly or through an impact (explosions), or pulsatively (hammers), or gradually (perforation).

p. 4 - 7. The authr's conclusion, based on the above formula I (p. 4) that the active force must be proportional to any stress, selected arbitrary, and that "the most advantageous normal" effect on the rock will occur in the case when "all stresses simultaneously acieve the ultimate strength" is wrong.

By the same reason, the statement (p. 5 and 6) that the breaking stress, expected according to the method recommended by the author), will nonetheless deviate from the true one and approach the mean breaking stress at various methods of application of force to rocks, is wrong. Since rocks and many construction materials are not regulated by the linear Hooke's law,is wrong the author's conclusion (p. 7) that great safety factor, accepted during designing the building structures, will cover all roughnesses of the method, suggested by the author, in the essence of the statistical method with all its defects and advantages.

Author's Response

No. 1. All conclusions of the Scientific and Technical Council are correct and well known by the author of the "Fixed Regulation". We also think that for people who are used to the common concepts of the strength of materials, the suggested theory must appear as a terrible heresy.

Table of values of rock temporary resistance to compression.

Породы. 1	$K_в$. Сопрот. сжатию в клг. на кв. сант. 2	Исследователь. 3	Типичная порода. 4	$K_в$. 5	f
6 Нефрит	3600—7900	Белелюбский. 50	—	—	—
7 Кварциты вообще	1500—3000	»	Кварцит крепкий 61	2000	20
8 Базальты вообще	1000—3000	Hütte нов. изд. 51	Базальт крепкий 62	2000	—
» »	1000—3200	» стар. изд. 52	—	—	-
9 Базальт Волынский	2850	Белелюбский. 53	— 63	—	—
10 Порфиры вообще	1000—3800	Hütte стар. изд. 54	Очень крепк. порфир	2000	—
» »	500—2000	» нов. изд. 55	—	-	—
11 Порфир Гохландск.	1000—1750	Белелюбский. 53	Порфир вообще 64	1500	15
12 Гранит весьма прочн.	1200—3000	Hütte нов. изд. 51	Гранит весьма креп.	1500	—
13 » Ав.-Венгрии	1300—3000	Ганим. 56	65	—	—
14 » Швейцарии	1100—1900	Тетмайер. 57	—	—	
15 » Гангоудский.	1406	Белелюбский. 53	Гранит вообще 66	1000	10
16 Сиенит вообще	800—2000	Hütte нов. изд. 51	-	—	—
17 Гранит, диорит, сиенит	800—2000	» стар. изд. 52	—	—	
18 Гранит прочный	800—1200	» нов. изд. 58	—	—	
19 » Воронежск.	936	Белелюбский. 53	—	—	—
20 » Сердобольск.	718	»	Мягкий гранит 67	800	[illegible]
21 » Выборгский	580—1296	»	—	-	—
22 Известн. Ав.-Венгр.	600—1500	Ганим. 56	-	—	—
23 » Швейцарии	900—1800	Тетмайер. 57	— 68	—	
24 » вообще	500—1500	Hütte стар. изд. 54	Самый крепкий известняк	1500	[illegible]
25 Мрамор вообще	500—1800	» нов. изд.	—	—	—
26 Плотный известняк	200—1600	» нов. изд. 55	—	—	—
27 Пористый известняк	200—600	» нов. изд.	Крепкий известняк	900	[illegible]
28 Извест. Севастоп. до	1296	Белелюбский. 53	- 69	-	—
29 » Ревельск.	500	»	-	-	-
30 » Мячковск.	453	»	—	—	—
31 » Воровского рудника	470	Гуськов. 59	70 Некрепкий известн	400	4
32 » Чудовский	511	Белелюбский. 53	—	-	—
33 Гатчинский	300	»	— 71	—	
34 Мячковский	187	»	Мягкий известняк	200	2
35 Старицкий	147	»	—	—	
36 Севастоп. от	81	»	Очень мягк. известн.	100	1
37 Одесский	76—240	»	- 72	—	
38 Песчан. Ав.-Венгрии	370—1400	Ганим. 56	-	-	—
39 Швейцарии	330—1630	Тетмайер. 57	Самый крепкий песчаник 73	1500	15
40 весьма плотные	1500—2000	Hütte нов. изд. 51	—		—
41 плотные	1000—1500	» нов. изд. 54	Крепкий песчаник 74	1000	10
42 средне-плотные	600—1000	» нов. изд. 55	—	—	
43 неплотные	600—1000	» нов. изд.	—		
44 угольн. вообще	500—1800	» стар. изд. 60	Обыкновенный песчаник 75	600	6
45 мергельные вообще	700—1800	» стар. изд. 60		—	—
46 бутовые и лещадные	500—1000	» стар. изд. 60	—	—	-
47 Павелецкие	511	Белелюбский. 53	Мягкий песчаник 76	300	3
48 Воровского рудника	605	Гуськов. 54	-	—	
49 То же	411	»	—	—	-

Key: (1) rocks; (2) resistance to compression in kilograms per square cm; (3) investigator; (4) typical rock; (5) kilograms; (6) nephrite; (7) quartzites in general; (8) basalts in general; (9) Volyn basalt; (10) porphuries in general; (11) Gohland porphyry; (12) very hard granite; (13) Austro-Hungarian; (14) Swiss; (15) Gangeud; (16) syenite in general; (17) granite, diorite, syenite; (18) hard granite; (19) Voronezh; (20) Serdobol'sk; (21) Vyborg; (22) Austro-Hungarian limestone; (23) Swiss; (24) in general; (25) marble in general; (26) dense limestone; (27 Porous limestone; (28) Sevastopol limestone up to ...; (29) Revel; (30) Machkovsk; (31) from Verovskiy mine; (32) Chudovo; (33) Gatchina; (34) Machkovsk; (35) Staritsk; (36) Sevastopol from ... ; (37) Odessa; (38) Austro-Hungarian sandstone; (39) Swiss; (40) very dense; (41) dense; (42) medium dense; (43) not dense; (44) coal sandstone in general; (45) marl sanstones in general; (46) quarrystone and bottom sandstones; (47) Paveletsk; (48) from Verovskiy mine; (49) same as above; (50) Belolyubskiy; (51) Hutte, new edition; (52) old edition; (53) Belolyubskiy; (54) Hutte, old edition; (55) new edition; (56) Ganish; (57) Tethmayer; (58) new edition; (59) Gus'kov; (60) old edition; (61) hard quartzite; (62) hard basalt; (63) very hard porphyry; (64) porphyry in general; (65) very hard granite; (66) granite in general; (67) soft granite; (68) the hardest limestone; (69) hard limestone; (70) not hard limestone; (71) soft limestone; (72) very soft limestone; (73) the hardest sandstone; (74) hard sandstone; (75) common sandstone; (76) soft sandstone.

Bur the core of the matter is that strict rules cannot be applied for solution of the pre-set problem; however, it is possible through the method suggested. The fact of the matter is whether the accepted error is within the permissible limits or not. Stones do not follow the Hooke's law, but we assume that they do. This is correct, but what is the error. The law of granite relative compression is usually expressed by a formula

$$e = \frac{1}{250,000} p^{1.132}$$

where e is relative compression, and p is stress. We assume that

$$e = \frac{1}{250,000} p^{1.000}$$

and obviously make an error by $\frac{1}{250,000} p^{0.132}$ times. No Hooke's law can be valid beyond proportionality.

This is correct, but we do not even need this. It is quite sufficient that stress diagrams are similar for various materials, i.e. the granite diagram is similar to the sandstone diagram, etc. In addition, the diagrams are only corresponding ones. The stretching diagram can be completely different from the compression diagram; stretching along the fibers can differ from stretching across them, etc. But in reality it is not quite so: diagrams are of similar nature, but they are not strictly equivalent. Therefore, with out assumption of equality, the problem is again reduced to a certain error. Moreover, it would be quite sufficient if the breaking stresses of various materials for compression were proportional to those for stretching, splitting-off, etc. No doubt that there is certain connection and, generally speaking, the harder is the material, the more resistance it has. However, there is no precise proportionality and assuming its existance we again make a certain error, etc. The question is if such errors are finally acceptable for practical purposes or not. If they are, then our whole approach is adequate. At the end, the problem is to be solved not by accuracy of our logical concepts which represent only an approach to the type of formulae (let us remember our preface: "All this is not precise laws of nature, but a key selected so that everybody could read easily the encoded book of practical data", but the summary table on relative rock hardness according to practice that, aside from many discussions, says that in general with accuracy sufficient for the ptactice (according to our multiple calculations, the difference is not greater than 25% in common cases) granites are 10 : 6 times harder for compression than common sandstones, and the same harder they are drilled. Also, they present the same times less pressure on the support, etc., i.e. they are 10 : 6 times harder than sandstones. If we compare this result with the fact that in bulding constructions the reserve is usually taken in 8-10 times, then even if we follow all rules of calculations and then assume such a reserve, the final accuracy of dimentions hardly can be higher than in calculations based on such rough assumptions as ours, but without further reserves; then we will have to accept that our methos is not too bad. However, such generalization of immense importance. Imagine the fastener making a lock for a timber frame from pinewood or oakwood. He applies a saw across the fibers, splits the wood with an ax along the fibers, cuts, cuts off, applied his ax slantly, straight, etc. Try to calculate his work theoretically. Divide it into elementary resistances to compression, splitting-off, stretching, etc. Derive formulae. Evidently, this is not possible. However, it is absolutely clear that, generally speaking, processing the oakwood requires more labor than the same processing the pinewood. By how many times? All depends on combination of elementary resistances, and if different cases it will not be quite the same. If there will be only stretching stresses, the sought ratio will be equal to their ration; in the case of compressing stresses only - it will be equal to the ratio of such; at the combination of both - it will be equal to some mean value. Let us turn to numbers. It appears that temporary resistance to oakwood stretching along the fibers is 1.34 times greater than that for the pinewood, to compression - by 1.31 times, to splittin-off - by 1.23 times, to bending - by 1.47 times, etc. Thus, if we assume that oakwood is generally 1.3 times harder than pinewood, then we will not make a big erroe at any combination of stresses. Here we do not care about formulae, stresses, existing combinations, etc., etc. In all cases the result is the same: oakwood is 1.3 times harder than pinewood and that is it. Good or bad, but we solved the problem that was absolutely impossible from the strictly scientific point of view. And we give ourselves special credit for the fact that we manages to find a certain line, some regularity among the chaos of the most rough, wrong, inaccurate, variable and contradictory observations. And absolutely wrong will be one who, afraid of lack of strictness in our considerations, deprives oneself of such a convenient method. Without this generalization no general standards are ever possible, because otherwise we have a series of separate, infinitely variable cases where each of them requires special examination.

Transition from the quantity of work A to coefficients of hardness f is made according to the formula

$$A = 2.3\, f \sqrt{f} \quad \text{or} \quad f = 0.57 \sqrt[3]{A^3}$$

	A	f
Soft slate	9	2.5
Hard slate	15	3.5
Common sandstone	32	6.1
Magnetite	40	6.7
Not hard gneiss	49	7.6
Chalcopyrite	60	8.7
Limestone	55	8.3
Hard sandstone	53	8.2
Hard greywacke	56	8.3
Very hard quartz-sand-stone	115	14
Dense quartz greywacke sandstone	112	13
Dense andradite	130	15
Dense adesinite	160	17
Dense augite-garnet rock	170	18
Very hard porphyry	190	19

We will also include observations of Uspenskiy over Kedabek rocks that are exclusive by their hardness (Records of the Institute of Mining, 1909, vol. II, ed. I).

Quartzite of highest hardness	1,890	87
Extremely hard quartzites and pophyrites	1,000	57
Very hard quartzites, kedabekites, porphyrites	600	40
Common Kedabek quartzites	300	26
Porous quartzites	100	12
Pyrites (copper and sulfurous)	60	8.7
Same as above with heavy spar	20	4.2

Here, suprisingly high numbers have been obtained for hard rocks. However, it seems that we can attribute this to the method of experiments: the impact force was taken as 1 kilogram-meter or four times less than the impact force of an average worker (4 kg-m). This is not sufficient for such hard rocks; this will be nocking rather than drilling. The author himself writes in the comment for the hardest sample: "It often happened that after 2,000 strikes with a quite sound drill, the depth of the hole would not change." The rocks are not that hard which was proved by the fact that the author was suprised to notice that Greek drillers would drill out by means of two-arm drilling the same amount in Kedabek quartzite as in Bogoslovsk rock where their A was only 170 - 200 kg-m.

Drilling with manual rotating perforators. If we group by rocks rather multiple data for various perforators, presented in the article of

Gus'kov (Gorniy Zhurnal, 1908, vol. 6, p. 328-336) and borrowed mainly from the book of Linke "Handbuch der Ingenierwissenschaften", then the following labot consumption per 1 cubic cm of a drilled blast-hole in kg-m can be obtained:

Rock	Work	f
Coal	4.0	1.6
Salt-bearing breccia	2.8	1.1
Marl	3.3	1.3
Rock salt	5.5	2.2
Soft clay shale	6.8	2.7
Hard clay shale	10.8	4.3
Sandstone	12.6	5.0
Limestone	14.0	5.6
Anhydrite	14.0	5.6
Granite, greywacke, gneiss, porphyry	40.6	16.0
Conglomerate	60.0	24.0

Having made preliminary calculation according to our nomenclature, we can see that 2.5 kg-m of work corresponds to one unit of hardness. Dividing the presented numbers by this value we obtain coefficients of hardness shown in the second column. Too high numbers were obtained for granite and conglomerates because of low adaptability of rotating perforators for such rocks.

(d) Drilling with pneumatic perforators. See the data further in paragraph 151. The coefficient of hardness are determined from the formula

$$c = \frac{46}{f} \text{ см.}$$

where c - drilling speed in 1 minute.

Rocks	c	f
Quartzite, very hard syenite	2.2	21
Adesinophyr, hard greywacke	3.4	14
Granitogneiss, spenite, veins, very hard sandstone, limestone	4.1	11
Zechstein, hard sandstone	5.8	8
Basaltic lava, speckled sandstone	7.5	6
Clay shale	9.5	4.8

(e) Manual drilling of blast-holes. There are data of Uspenskiy for the Bogoslovsk area (Gorniy Zhurnal, 1907, vol. 6, p. 265) where the numbers for the drilling speed for 1 minute are presented. Having taken the average for upward and downward drilling is comparing preliminary according to our nomenclature we see that the average drilling speed is expressed by the formula:

— 14 —

$$c = \frac{5,8}{f} \text{ см.}$$

from here

$$f = \frac{5,8}{c}$$

The calculated numbers of f are shown in the second column:

Rock	c	f
Not hard limestone	1.00	5.8
Magnetite	0.93	6.2
Copper and magnetic pyrite	0.83	7.0
Hard sandstone	0.80	7.2
Dense limestone	0.65	8.9
Dense andradite	0.46	12,6
Dense andesinite	0.43	13.6
Augite-garnite rock	0.46	12.6
Porphyrite	0.37	15.6

We will show further in paragraph 102 that on the basis of the data from the Donetsk Basin (operations of a coal cutter) it was established that f for soft coal can be taken from 0.6 to 1.0, 0.7 on the average,; for medium coal f is from 1.0 to 1.4, 1.2 as an average; and for hard coal f fluctuates from 1.4 to 1.8, 1.6 averagely, reacing 2.0. The hardness of soft slate during drift blasting in the Donetsk Basin is determined (paragraph 107) as 2.4.

(f) Finally, we want to mention the detailed data of Sal'monovich (Instruction for Preparation of Estimates, 1907, vil. II, p. 6 and 13), where there are data concerning manual and earth works. The presented data are covered by the formula

$$A = 2f$$

where A is the number of workers per cubic sajene. The calculated f is shown immediately in the summary table. Other details can be found in our Short Course of Mining (Tashkent, 1921), p. 90-98. Now all these data can be arranged in one general table.

Категория и № типичные породы. 1	Наименование породы. 2	Раздробляемость [illegible] 3	Коэффициент крепости 4	Ручная работа по [illegible] 5	Сопротивление [illegible] 6	Добавления: по Ренке 8	Добавления: по Долемагну 9	Добавления: по Протодьяконову 10	Работа на дробление [illegible] 11	Ручное бурение: по Ренке 12	Ручное бурение: по Долемагну 13	Ручное бурение: по Деннис Еис.	Ручное бурение: по Уссингу 14	Воздушн. перфоратор 15	Электр. перфоратор 16	[illegible] 17	[illegible] 18	[illegible] 19	[illegible] 20	[illegible] 21
Исключительные породы. 22	Кремнистый К[illegible]кий кварцит 25								87,0											
	Порфир 24	1600-7900																		
	Чрезвычайно крепкие Кузбасские кварциты и порфириты 25								87,0											
	Очень крепкие Кузбасские кварциты и порфириты 26								40,0											
	Базальт В[illegible] 27	2850																		
I. 41 Высшей степени крепкие породы.	Кварцит крепкий 28	3000																		
	Базальт крепкий ... 29	2000																		
	Очень крепкий кварцевый порфир 30	3000																		
	Кузбасский кварцит ... 31								16,0											
	Кварцит, очень крепкий [illegible] 32		20											21,0	24,0					
	Кремень [illegible] 33																			
	Весьма вязкий порфирит 34								19,0											
Кварцит 42	Железистый кварцит 35				21,0															
	Кварцит, [illegible] порфир, базальт 36					18,0				10,0										
II.	Порфир [illegible] .. 37	1600																		
	Гранит весьма крепкий. 38	1500																		
	Самый крепкий песчаник 39	1800																		
	Самый крепкий известняк . 40	1800																		

Table of relative hardness of rocks.

Key: (1) categories and typical rocks; (2) observed rocks; (3) crushing force, kg per square cm; (4) coefficients of hardness; (5) manual operations according to Sal'monovich; (6) resistance to abrasion according to Rochefor; (7) extraction; (8) according to Rzhikha; (9) according to Dolezhalek; (10) according to Protodyakonov; (11) drilling-out operations according to various authors; (12) manual drilling; (13) according to Donetsk Basin; (14) according to Uspenskiy; (15) pneumatic perforators; (16) rotating perforators; (17) explosion according to Chalon; (18) pressure on support according to Protodyakonov; (19) surface subsidence according to Rzhikha; (20) finishing hewing according to fixed regulation for construction workers; (21) pneumatic hammer according to Donetsk Basin; (22) exclusive rocks; (23) the hardest Kedabek quartzite; (24) nephrite; (25) extremely hard Kedabek quartzites and porphyrites; (26) very hard Kedabek quartzites and porphyrites; (27) Volyn basalt; (28) hard quartzite; (29) hard basalt; (30) very hard quartz-porphyry; (31) Kedabek quartzite; (32) quartzite, very hard syenite; (33) conglomerate; (34) Bogoslovsk porphyrite; (35) Shokshino quartzite; (36) quartzite, quartz porphyry basalt; (37) porphyry in general; (38) very hard granite; (39) the hardest limestone; (40) the hardest sandstone; (41) extremely hard rocks; (42) quartzite.

1 II. Очень крепкие породы	Плотная авгито-гранитовая порода 5.								18,0				12,6							
	Плотный андезит 6.								17,0				12,6	14,0						
	Плотная [illegible] 7								15,0				12,6							
	Очень крепкий кварцевый песчаник 8								14,0											
	Плотный кварцев. грауввак. песчаник 9								18,0											
	Пористый К[illegible]ский кварцит . . 10								12,0											
2 Кварцевый порфир	Гранит, граувакка, гнейс, порфир . 11.		15												16,0					
	Крепкая граувакка 12													17,0						
	Порфирит Б[illegible] 13												15,6							
	Порфир южного берега Крыма 14.																		14,7	
	Гранит Г[illegible]ский 15	1408																		
	Кварц, крепкий гранит 16	—														12,5				
	Булыжник речной . 17																		12,4	
	Гранит Сердобольский 18				12,0															
	Гранит средний . . . . . . 19 . . .	1000															10,0			
	Крепкий песчаник . 20	1000																		11,2
	21 Гранито-гнейс, сиенит, жильная порода, очень крепкий песчаник, твердый известняк, известняк	—												11,2						
3 III. Крепкие породы.	Серый гранит . . . 22																		12,2	
	Красный гранит, булыжник и [illegible] 23																		10,0	
	Крепкий известняк . . . . 24 . . .											10,0								
	25 Гранит, сиенит, гнейс, [illegible]ные породы, крепкая граувакка, большинство руд, большинство порфиров, крепкие известняки, песчаники крепкие . .	—	18			10,0														
4 Гранит	Гранит Воронежский 26	936																		
	Гранит, песчаник, порфир, граувакка, гнейс, трапп . . 27						10,0				10,0									
	Гранит, порфир, гнейс 28															10,0				
	Сред. одних только [illegible]ст. пород 29	-																10,0		
	Крепкий известняк . . . . 30.	—																		10,7

Continuation

Key: (1) very hard rocks; (2) quartz-porphyry; (3) hard rocks; (4) granite; (5) dense augite-garnet rock; (6) dense andesinite; (7) dense andradite; (8) very hard quartz-sandstone; (9) dense quartz greywacke sanstone; (10) porous Kedabek quartzite; (11) granite, greywacke, gneiss, porphyry; (12) hard greywacke; (13) Bogoslovsk porphyrite; (14) porphyry of South Crimea; (15) Gangeud granite; (16) quartz, hard granite; (17) river cobble; (18) Serdobol'sk granite; (19) medium granite; (20) hard sandstone; (21) granito-gneiss, syenite, vein rock, very hard sandstone, hard limestone, limestone; (22) grey granite; (23) red granite, field cobble; (24) hard limestone; (25) granite, syenite, gneiss, greenrocks, hard greywacke, majority of ores, majority of porphyries, hard limestones, hard sandstones; (26) Voronezh granite; (27) granite, serpentine, porphyry, greywacke, gneiss, trachyte; (28) granite, porphyry, gneiss; (29) layers of only stone rocks; (30) hard limestone.

1 IIIa. [illegible]	4	Гранит [illegible]	800	8.6
	5	К[illegible] [illegible]	800	8.0, 8.0
	6	Хотинский гранит		8.0
	7	Ставропольский [illegible]		7.8
	8	К[illegible] песчаник		7.1
	9	К[illegible] граувакк		8.3
	10	К[illegible] песчаник		8, 8.2, 7.2, 8.1
	11	Известняк плотный		8.8, 8.9
	12	Медный колчедан		8.7, 7.0
	13	Пермский гипс		7.6
		Цехштейн, [illegible] песчаник, песчаник		7.9
	14	Татарский песчаник (Московский)		8.0, 7.0
2 IV Девонские [illegible] породы	15	Брянский сланец, [illegible] известняк		6.8
	16	Обыкновенный песчаник	600	6.1, 6.0, 6.0, 6.0
	17	Песчаник Верхнего рудника	606	
	18	Мергельный [illegible]		6.7, 6.8
	19	Ангидрид, известняк		5.8
	20	[illegible] дав, пестрый песчаник и желтый песчаник		6.0
	21	[illegible] известняк		5.8
	22	[illegible] известковый песчаник		5.6
3 [illegible]	23	[illegible] сланец, [illegible] сланец, пестрый песчаник, красный [illegible], известняк, [illegible]		8, 6.5, 6.7
	24	Гнейс, [illegible] сланец, гранит, доломит, известняк, песчаник, [illegible]		7.0, 7.0
	25	Преобладающие [illegible] с[illegible] со сланцеватыми, [illegible], [illegible] сланцы		6.0

Continuation

Key: (1) dense limestone; (2) rather hard rocks; (3) common sandstone; (4) soft granite; (5) hard limestone; (6) Khotin granite; (7) Stavropol scree; (8) Kishinyov sandstone; (9) hard greywacke; (10) hard sandstone; (11) dense limestone; (12) copper pyrite; (13) not hard gneiss; (14) zechstein, hard sandstone, sandstone, Tatarovsk (Moscow) sandstone; (15) hard shale, granular limestone; (16) common sandstone; (17) sandstone from Verovskiy mine; (18) magnetite; (19) anhydride, limestone; (20) basaltic lava, speckled sandstone and yellow sandstone; (21) not hard limestone; (22) Kislovodsk calcareous sandstone, mica slate, greywacke slate, speckled sandstone, red mud sill, limestone, ironstones; (24) gneiss, mica slate, trachyte, dolomite, limestone, sandstone, conglomerate; (25) predominant stone layers mixed with slate, marl , and clay layers.

IVa. 1 Некрепкие известняки	Песчанистый сланец, сланцеватый песчаник . 5			5,0
	Некрепкий известняк: Ревельский 6	640		
	" " 7 Мячковский (подольский)	453	5	2.8
	" " 8 Чудовский	511		
	" " 9 Нерчинск. руды	470		
	Песчаник . 9-a			5.0
V. 2 Средние породы	Крепкий глинистый сланец . 10	400		3.5 4,0 4.8 4.7 4,0 3,8
	Колчеданы с тяжелым шпатом . 11			4.2
	Кремнистый сланец, глинистый сланец, мягкий известняк, крепкий мергель, каменная соль . 12			4.4
3 Крепкий глинистый сланец	Тальковый сланец, глинистый сланец, гипс, мел . 13		4	4,0 4.7
	Сланец, известняк . 14			4.0
	Преобладающие слои мергелей, глин, суглинков, тонкие пласты угля и среди них кремнистые породы . 15			4.0
	Мраморы . 16			4,0
Va. 4 Средние сланцы	Плотная сланцеватая глина, мергель, морской грунт . 17			3,0
	Средние сланцы, мягкие песчаники 18	300		3.0 3,0
	Гатчинский известняк 19	300		3,0
	Брянский песчаник 20			3,0
	Воронежский известняк 21		3	3,0
	Пятигорский 22			2,2
	Кунгурский 23			2,2
	Жогу... 24			2,2

23

Continuation.

Key: (1) Not hard limestone; (2) medium rocks; (3) hard clar shale; (4) medium slates; (5) sandy shale schistose sandstone; (6) not hard limestone: Revel; (7) Machkovsk (semi-wild); (8) Chudovo; (9) from Verovskiy mine; (9a) sandstone; (10) hard clay shale; (11) pyrites with heavy spar; (12) roof shale, clay shale, soft limestone, hard marl, rock salt; (13) talc schist, clay shale, gypsum, chalk; (14) shale, limestone; (15) predominant layers of marls, clays, loams, thin layers of coal and stone rocks among them; (16) marbles; (17) dense slate clay, marl. frozen soil; (18) medium slates, soft sandstones; (19) Gatchina limestone; (20) Bremen sandstone; (21) Baku limestone; Pyatigorsk limestone; (22) Kukersk limestone; (24) Zheguli limestone.

VI. 1 Довольно мягкие породы.	Мягкий глинистый сланец 4	300	2.4 2.5 2.0 2.7 2.0 2.6
	Антрацит 5	196	2.0 2.0
	Мягкий известняк 6	200	
	Каменная соль . 7	—	2.6
	Ставропольский известковый песчаник 8		1.9
	Мячковский известняк мягкий 9	187	1.8 1.8
	Старицкий . 10 .	147	1.9
	[illegible]ский . 11 .		
2 Мягкий глинистый сланец.	Грунты, добываемые ломом и кайлами с клиньями (слежавшаяся глина, мергель, разрушенные песчаники, мерзлые известняки, мерзлый грунт, мел) 12		2 2.0
	Уголь, мел . 13		2.0
	Мощные толщи сланцев, мергелей, глин . 14		2.0
	Гипс, разрушенный гнейс и гранит, мергель, глина, бурый уголь . . 15	—	2.0
	Разрушенные и выветрившиеся скалистые породы, сильно слоистый сланец, мягкие мергели, крепкая сланцевая глина, тальковый сланец, некоторые угли 16		1.6
3 VIa. Щебенистый грунт.	Щебенистый грунт, добываемый кайлом и ломом, разрушенный сланец, слежавшиеся сцементированные гравий и щебень, сланцеватая глина 17		1.8 1.5
	Толща сырого песку, ила, галечника с прослойками мергелей, глины и пр. 18		1.5 1.8
	Крепкий уголь 19		1.5 1.6 1.6
	Сол[illegible] брекчия 20		1.5
	Мергель 21		1.3

Continuation.

Key: (1) rather soft rocks; (2) soft clay shale; (3) rock debris soil; (4) soft clay shale; (5) anthracyte; (6) soft limestone; (7) rocj salt; (8) Stavropol limestone sandstone; (9) Machkovsk soft limestone; (10) Staritsk soft limestone; (11) Inkerman soft limestone; (12) soils extracted by means of a crow-bar and wedges with a hammer (schistous clay, marl, broken sandstones, porous limestones, frozen soil, chalk); (13) coal, chalk; (14) thick series of slates, marls, clays; (15) gypsum, broken gneiss and granite, marl, clay, brown coal; (16) broken and weathered rocks, heavily laminated slate, soft marls, hard binding clay, talcschist, some coals; (17) rock debris soil, extracted by a pike and a crow-bar, broken slate, slightly cemented gravel and rock debris, schistous clay; (18) series of wet sand, mud, shingle with layers of marls, clay, etc.; (19) hard coal; salt-bearing breccia; (21) marl.

VII 1 Мягкие породы 2 Глина	Грунты, добываемые острой лопатой с долбом, сухая глина, слежавшийся гравий . . . 8 Бурый уголь . . . 9 Самые мягкие известняки: 10 [illegible] . . . 10 [illegible] . . . 11 [illegible] . . . 12 Мягкие залежи [illegible], галечник, щебень . . . 13 Иловатый гравий, иловатый песок . 14 Большинство глин, сухой песок, осыпи, очень мягкие черепки в глине, отдельные бурые угли . . . 15	0.9; 1.0; 1.0; 1.2; 1.0; 1.0; 0.6; 0.7; 1.0; 1.0; 0.9
VIIa 3 Песчаная глина	Песчаная глина, крупный гравий, легкая глина, добываемые лопатой с широким концом . . 16 Мягкий уголь . . . 17 Каменный щебень, закладка . 18	0.8; 0.65; 0.8; 0.84
VIII 4 [illegible] Породы	Чернозем, легкий суглинок и [illegible], выкапываемые лопатой . . . 19 Илистый песок . . . 20 Илистый торф . . . 21 Торфянистый грунт, земля с примесью щебня или мусора . 22	0.8; 0.50; 0.6; 0.8; 0.6
IX 5 Сыпучие породы Песок 6	Песок, насыпная разрыхленная земля, мелкий гравий . . . 23 Сухой песок, осыпи . . . 24 Гравий, песок, растительная земля, торф осыпи, уже добытые массы . 25	0.5; 0.4; 0.5; 0.60
X 7 Плывуны	Плывун, разжиженный грунт, болотистый грунт . . . . . 26. . . .	0.2; 0.20

Continuation

Key: (1) soft rocks; (2) clay; (3) sandy clay; (4) earth rocks, chernozem; (5) loose rocks, sand; (6) quicksand; (7) soild extracted by means of a sharp pike with a crow-bar, dry clay, caked gravel; (9) medium coal; (10) the softest limestones: Sevastopol limestone from ...; (11) Vyatka limestone; (12) Ternovsk limestone; (13) thick deposits of wet sand, shingle, rock debris; (14) muddy gravel, muddy sand; (15) majority of clays, dry sand, talus, very soft marls and clays, certain brown coals; (16) sandy clay, large gravel, light clay extracted by means of a pike with wide edge; (17) soft coal; (18) stony rock debris, filling; (19) chernozem, light loam, etc., extracted by means of a spade; (20) detrital deposits, sand; (21) quicksands, peat; (22) peaty soil, soil with chips or garbage; (23) sand, deposited loosened soil, small gravel; (24) dry sand, talus; (25) gravel, sand, sod, talus peat, already extracted masses; (26) quicksand, diluted soil, marshy soil.

This Table leaves no doubts about evident proportionality of relative rock hardness in various relationships, in all variety of cases, with observers absolutely independent of each other, and, of course, with inaccuracy of data. This proves the possibility of a single general classification of rocks by the coefficient of hardness, and also the very coefficients have been established. They were used for compilating the Table.

In order to avoid confusion, we should mention that, according to the meaning of the conclusion, in the case of the established relative rock hardness, the amount of work required per unit is not always simply proportional to it because this needs identical conditions of comparison; for example, workings of the same section must be compared, explosive materials must be the same, drills must have the corresponding taper angle, etc. If these conditions are not met, the work can be found not proportional to f. Secondly, the derived coefficients of hardness refer to the entire group of rocks, for example "hard granites", "soft sandstones", but they cannot be applied to any sample or to any individual practical case. The experiments of Uspenskiy show vividly that in the same sample, throughout of only 5 cm of the blast-hole length, hardness sometimes changed 10 times or more. Therefore, the number of the Table, quite sufficient for a whole mine or working, will require a special definition for an individual case as it is given in the next paragraph.

Paragraph 2. Determination of a coefficient of hardness of the given rock. If in some case we must determine directly the coefficient of hardness of the given rock, this can be done through the following methods:

(a) According to the crushing force. For rocks that can sustain a compression test, the unit of the coefficient of hardness corresponds to crushing force of 1000 kg per 1 square cm.

Example. Imagine that this sandstone is crushed by a load of 735 kg per 1 cm^2. Than the coefficient of hardness is

$$f = 735 : 100 = 7.35$$

(b) According to the amount of labor spent for drilling out 1 cm^3 of rock. The coefficient of hardness can be determined from the expression

$$f = \frac{a}{4.0} \operatorname{cotg} \left(\varphi + \frac{\alpha}{2} \right)$$

where a is amount of work spent for drilling out 1 cm^3 of rock during laboratory experiments in kg-m.
φ - angle of friction of a drill against the rock (11-19°; lower at dry drilling, higher at wet drilling).
a is the taper angle of the dril (from 60° in soft rocks and up to 110° in hard rocks).

We can consider approximately that

$$tg\left(\varphi + \frac{\alpha}{2}\right) = \frac{\sqrt{f}}{2}$$

and then approximately

$$f = 0.52 \sqrt[3]{a^2}$$

Example. Imagine that drilling out of 1 cm^3 of the given rock requires, according to the laboratory tests, 45 kg-m. Let angle $\varphi = 11^\circ$ and $\alpha = 85^\circ$. Then

$$f = \frac{45}{4{,}6}\, ctg\left(11^\circ + \frac{85^\circ}{2}\right) = 7{,}3$$

An approximate formula gives

$$f = 0.57 \sqrt[3]{45^2} = 7.2$$

a кгм (1)	2,3	6,6	11,8	18,0	26	34	43	53	62	73
f	1	2	3	4	5	6	7	8	9	10
a кгм	84	96	108	121	134	148	162	170	190	206
f	11	12	13	14	15	16	17	18	19	20

Table for transition from the amount of work a to the coefficient of hardness f.

Key: (1) kg-m.

(c) According to the efficiency of a driller during the shift. If in the case of one-arm drilling with a hammer, the driller drills out L running meters of the horizontal blast-hole during 8-hour shift, then

$$f = \frac{8.5}{L}$$

Example. Imagine that in the given rock the driller drills 1.15 running meters, then

$$f - \frac{8,5}{1.15} \quad 7,4$$

Comment. The above method is the simplest and practically available.

L пог. метр. (1)	5,7	4,3	2,8	2,1	1,7	1,4	1,2	1,0	0,94	0,86
f	1,5	2,0	3,0	4,0	5.0	6,0	7,0	8,0	9,0	10
L пог. метр.	0,77	0,71	0,65	0,61	0,57	0.53	0,50	0,47	0,45	0,43
f	11	12	13	14	15	16	17	18	19	20

Table for transition from the length of a drilled blast-hole during one shift to the coefficient of hardness.

Key: (1) L of running meters.

(e). According to the quantity of explosive material. If while sinking some working with the cross-section of 8 m^2, Q kg of blasting gelatin were spent per 1 m^3 of the rock in the massiff, then

$$f=6.25\left(\sqrt{2,63\,Q} - \frac{1}{\sqrt{S}}\right)^2$$

Example. Imagine that Q is equal to 1 kg. Section S = 2 x 2 m^2. Then

$$f = 6,25\left(\sqrt{2,63 . 1,00} \quad \frac{1}{\sqrt{4.00}}\right)^2 \quad 7,6$$

Comment 1. In the case when the explosive material is not blasting gelatin with 93% of nitroglycerin but anything else, then Q should be interpreted as an amount of blasting gelatin of the above composition, equivalent to the observed consumption. See transition multipliers further (paragraph 169)

Comment 2. The above method needs very careful determination of the consumption of explosive material because a small error in determining the value of Q produces very substantial fluctuations of the value f; however, in practice Q is a very random value and it depends on the decision of a person who conducts operations. Sometimes they try to save on explosives, sometimes they spend excessively.

(e) According to efficiency of a driver and production. The coefficient f for rocks that are mined manually is determined from the expression

$$f = \frac{A\sqrt[4]{S}}{0.55} \quad \text{or} \quad f = \frac{A\sqrt{s}}{0.55}$$

where A is the amount of day labor per 1 m^3 of production, s - face area per one coal cutter, S - cross-section of working in square meters.

The first formula should be taken when s is not known before.

Example. Imagine that two coal cutters sink the drift with the section of 4.55 m^2 in solid coak without explosives and during the shift they move the working by 0.71 m. Then there is 0.62 day labor per 1 m^3, i.e. A = 0.62 and s = 2.27 m^2. Hence

$$f = \frac{0.62\sqrt{2.27}}{0.55} = 1.69$$

[illegible]	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	[illegible]	∞
1	[illegible]	0.52	0.41	0.35	0.32	0.29	0.28	0.27	0.26	0.24	0.21	0.20	0.19	0.19	0.17	0.16	0.11
2	[illegible]	[illegible]	0.47	0.41	0.37	0.34	0.33	0.32	0.30	0.28	0.26	0.24	0.23	0.22	0.21	0.20	0.16
3	1.09	0.75	0.60	0.53	0.46	0.44	0.43	0.42	0.39	0.37	0.36	0.34	0.31	0.30	0.29	0.29	[illegible]
4	1.21	[illegible]	0.71	0.64	0.56	0.53	0.52	0.51	0.49	0.46	0.44	0.41	0.40	0.39	0.38	0.37	[illegible]
5	1.35	[illegible]	0.83	0.75	0.66	0.63	0.62	0.61	0.59	0.55	0.53	0.50	0.49	0.47	0.46	0.46	[illegible]
6	1.46	1.07	0.90	0.84	0.76	0.72	0.71	0.70	0.65	0.64	0.61	0.59	0.56	0.54	[illegible]	[illegible]	[illegible]
7	1.59	1.19	1.08	0.94	0.86	0.82	0.80	0.78	0.76	0.73	0.69	0.66	0.64	0.62	0.61	[illegible]	[illegible]
8	1.71	1.29	1.13	1.03	0.96	0.92	0.90	0.87	0.86	0.82	0.77	0.73	0.71	0.70	[illegible]	0.67	[illegible]
9	1.83	1.39	1.23	1.18	1.06	1.01	0.98	0.96	0.93	0.91	0.86	0.81	0.79	0.77	0.76	0.75	[illegible]
10	1.94	1.60	1.33	1.22	1.15	1.11	1.07	1.06	1.02	1.00	0.93	0.90	0.87	0.86	0.84	0.83	0.78
11	2.06	1.60	1.42	1.31	1.24	1.19	1.15	1.12	1.10	1.08	1.01	0.97	0.94	0.92	0.91	0.90	[illegible]
12	2.17	1.69	1.51	1.39	1.32	1.27	1.23	1.20	1.18	1.16	1.09	1.06	1.02	1.00	0.99	0.97	[illegible]
13	2.28	1.79	1.61	1.47	1.41	1.35	1.31	1.28	1.26	1.23	1.16	1.13	1.09	1.07	1.06	1.04	[illegible]
14	2.39	1.88	1.70	1.56	1.49	1.44	1.40	1.36	1.34	1.31	1.24	1.21	1.17	1.14	1.13	1.12	1.06
15	2.48	1.98	1.79	1.64	1.57	1.52	1.48	1.44	1.42	1.39	1.32	1.27	1.24	1.22	1.20	1.19	1.15
16	[illegible]	2.07	1.89	1.73	1.66	1.60	1.56	1.52	1.50	1.47	1.39	1.35	1.32	1.29	1.27	1.26	1.20
17	2.60	2.16	1.94	1.82	1.74	1.69	1.64	1.60	1.58	1.55	1.47	1.42	1.39	1.37	1.36	1.30	[illegible]
18	2.70	2.26	2.08	1.91	1.83	1.77	1.73	1.69	1.66	1.63	1.56	1.50	1.46	1.44	1.42	1.41	[illegible]
19	2.89	2.35	2.11	2.00	1.91	1.86	1.81	1.77	1.74	1.71	1.63	1.57	1.54	1.51	1.49	1.46	1.43
20	[illegible]	2.44	2.22	2.09	1.99	1.93	1.89	1.86	1.82	1.79	1.70	1.65	1.61	1.59	1.57	1.55	[illegible]

Table for transition from the quantity of blasting gelatin per 1 m^3 of working to the coefficient of hardness.

The quantity of blasting gelating is given in kg.

Key: (1) S in square meters.

S	1	2	3	4	5	6	7	8	9	10	15	20 кв. метр.
0.4	0.24	0.21	0.19	0.17	0.16	0.15	0.15	0.14	0.14	0.13	0.12	0.11
0.5	0.30	0.27	0.23	0.21	0.20	0.19	0.18	0.18	0.17	0.17	0.15	0.14
0.6	0.36	0.32	0.28	0.25	0.24	0.23	0.22	0.21	0.21	0.20	0.18	0.17
0.7	0.42	0.38	0.33	0.30	0.28	0.27	0.26	0.25	0.24	0.24	0.21	0.20
0.8	0.48	0.43	0.37	0.34	0.32	0.31	0.30	0.29	0.28	0.27	0.24	0.23
0.9	0.54	0.48	0.42	0.38	0.36	0.35	0.34	0.32	0.31	0.30	0.27	0.26
1.0	0.60	0.54	0.47	0.42	0.40	0.38	0.37	0.36	0.35	0.34	0.30	0.29
1.1	0.66	0.59	0.51	0.47	0.44	0.42	0.40	0.39	0.38	0.37	0.33	0.32
1.2	0.72	0.64	0.56	0.51	0.48	0.45	0.44	0.43	0.42	0.40	0.36	0.34
1.3	0.78	0.70	0.61	0.55	0.52	0.50	0.48	0.46	0.45	0.44	0.39	0.37
1.4	0.84	0.75	0.66	0.59	0.56	0.54	0.52	0.50	0.49	0.47	0.42	0.40
1.5	0.90	0.81	0.70	0.63	0.60	0.58	0.56	0.54	0.52	0.51	0.45	0.43
1.6	0.96	0.86	0.75	0.68	0.64	0.62	0.59	0.57	0.56	0.54	0.48	0.46
1.7	1.02	0.91	0.80	0.72	0.68	0.66	0.63	0.61	[illegible]	0.57	0.52	0.49
1.8	1.08	0.96	0.84	0.76	0.72	0.70	0.66	0.64	[illegible]	0.61	0.55	0.52
1.9	1.14	1.02	0.87	0.80	0.76	0.74	0.70	0.68	0.66	[illegible]	0.58	0.55
2.0	1.20	1.07	0.92	0.84	0.80	0.77	0.74	0.71	0.69	0.67	0.61	0.57

Table for transition from the number of drivers per 1 m^3 of working to coefficients of hardness.

Day labor of drivers.

Key: (1) 20 m^2.

For operations with the use of explosives, the coefficient can be determined from the expression

$$f = A \sqrt[4]{S}$$

where A - the number of drivers, i.e. drillers and rockworkers together, but without workers engaged in taking away the rock or its lifting; S - cross-section of the working in square meters.

Comment. This is a very convenient method because the corresponding data are usually available in mines.

Example. Imagine that in the cross-entry with its section of 4.55 m^2, there are 5.0 day labor of drillers (for drilling and rock removal) per 1 m^3 of a mass. Then

$$f = 5.0 \sqrt[4]{4.55} = 7.3.$$

f \ S	1	2	3	4	5	6	7	8	9	10	15	20
1.5	1.5	1.3	1.1	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.7
2.0	2.0	1.7	1.5	1.4	1.3	1.3	1.2	1.2	1.2	1.1	1.0	1.0
3.0	3.0	2.5	2.3	2.1	2.0	1.9	1.8	1.8	1.7	1.7	1.5	1.4
4.0	4.0	3.4	3.0	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.0	1.9
5.0	5.0	4.2	3.8	3.5	3.3	3.2	3.1	3.0	2.9	2.8	2.5	2.4
6.0	6.0	5.0	4.6	4.3	4.0	3.8	3.7	3.6	3.5	3.4	3.0	2.8
7.0	7.0	5.9	5.3	5.0	4.7	4.5	4.3	4.2	4.0	3.9	3.6	3.3
8.0	8.0	6.7	6.1	5.7	5.3	5.1	4.9	4.8	4.6	4.5	4.1	3.8
9.0	9.0	7.6	6.8	6.4	6.0	5.7	5.5	5.3	5.2	5.1	4.6	4.3
10	10	8.4	7.6	7.1	6.7	6.4	6.1	6.0	5.8	5.6	5.1	4.7
11	11	9.2	8.3	7.8	7.3	7.0	6.8	6.5	6.4	6.2	5.6	5.2
12	12	10	9.1	8.5	8.0	7.6	7.4	7.1	6.9	6.7	6.1	5.7
13	13	11	9.8	9.2	8.7	8.3	8.0	7.7	7.5	7.3	6.6	6.2
14	14	12	11	9.9	9.3	8.9	8.6	8.3	8.1	7.9	7.1	6.6
15	15	13	11	11	10	10	9.2	8.9	8.7	8.4	7.6	7.1
16	16	13	12	11	11	10	9.8	9.6	9.3	9.0	8.1	7.6
17	17	14	13	12	12	11	10	10	9.8	9.6	8.6	8.1
18	18	15	14	13	13	11	11	11	10	10	9.1	8.5
19	19	16	14	13	13	12	12	11	11	11	9.7	9.0
20	20	17	15	14	14	13	12	12	12	11	10	9.5

Table for transition from the number of drillers per 1 m^3 to coefficients of hardness f.

(f) According to efficiency of a navvy on the surface. If the number of navvies per 1 m^3 during surface operations is known, the the coefficient of hardness can be found from the expression

$$f = 3.33 A$$

Example. Imagine that during excavation of dense dry clay to the surface it was found that 0.4 of day labor of a worker was required for 1 m^3. Then

$$f = 3.33 \quad 0.4 = 1.33$$

(g) According to sinking speed of a working. If we take an adit working with the section of S m^3 under all normal conditions, then designating through c the speed of its movement per shift during a month consisting of 24 working days, the value of the coefficient of hardness can be determined from the expression:

1) for sinking exclusively by means of explosive operations

$$f = \frac{42}{c\sqrt[4]{S}}$$

2) for manual cutting and breaking with explosives

$$f = \frac{35}{c\sqrt[4]{S}}$$

3) for sinking by means of manual operations exclusively

$$f = \frac{28}{c\sqrt[4]{S}}$$

Examples. Imagine that working in two shifts, they sink 3.6 meters in a month in hard porphyry; the section is 5 m^2. Then

$$f \cdot \frac{42}{0,5.3,6\sqrt[4]{5,00}} \quad 15,6$$

Now imagine that in a Turkestan coal-mine, two coal cutters, working with two manual cuts on the sides and with breaking by means of gun-powder, usually sink forward by 15 meters within a month (24 working days, one-shift work) in the drift with its section of 4.55 m^2. Then

$$f \quad \frac{35}{15\sqrt[4]{4,55}} \quad 1,6$$

And imagine finally that working with the same coal under the same conditions they move only by 12 meters. Then

$$f = \frac{28}{12\sqrt[4]{4.50}} = 1.6$$

Comment. This method is the simplest of all described. However, being the final result of quite a few various operations and circumstances, calculation according to this method requires that everything should take place under absolutely normal conditions. In addition, excavation must take place totally in the given rock.

Comment to the whole paragraph. If for some rock the coefficient of hardness is determined through several methods, this inevitably results in a certain difference between various determinations. When this difference is not big, the mean value should be taken. If the difference is substantial, which, for example, can result from circumstances indicated in the comment 2 to paragraph 1, then the coefficient f should be treated as not the same in various relations and its special value must be taken for each case.

Examples. Imagine that for some sandstone were obtained the values given in the above samples, i.e.

according to method (a)	7.35
according to method (b)	7.30
according to method (c)	7.40
according to method (d)	7.60

Then, the mean value 7.4 can be taken for f.

But imagine now that for some very soft but viscous limestone was obtained value f, determined through blast-hole drilling (method c) equal to 3.4, and according to the quantity of explosives (method d) - it is 5.7. Then for each relation we must take these very values or, having taken the mean f = 4.6, we must agree with substantial error.

Substantiations for the whole paragraph. All above formulae are derived further in corresponding places. The method of calculations is evident from "Fundamentals" of the paragraph 1. In general, this paragraph is determination of coefficients of hardness in accordance with the given efficiency of a worker and it is nothing else but an operation that is opposite to all subsequent, i.e to determination of efficiency of operations according to coefficients of hardness. Since the basis consists of practical data, the reverse operation must inevitably end at them and there should not be any difference with practice.

S в м. н. / l	1	2	3	4	5	6	7	8	9	10	15	20
2 А) Проходка со взрывчатыми материалами без ручного труда.												
1,5	28	24	21	20	19	18	17	17	16	15	14	13
2	21	18	16	15	14	14	13	13	12	11	11	10
3	14	12	11	10	9,3	9,0	8,7	8,5	8,2	7,4	7,2	6,7
4	10	9,1	8,0	7,5	7,0	6,7	6,6	6,3	6,1	5,6	5,4	5,0
5	8,3	7,3	6,3	6,0	5,6	5,4	5,2	5,1	4,9	4,4	4,3	4,0
6	7,0	6,1	5,3	5,0	4,7	4,5	4,4	4,2	4,1	3,7	3,6	3,3
7	6,0	5,2	4,5	4,3	4,0	3,8	3,7	3,6	3,5	3,2	3,1	2,8
8	5,2	4,6	4,0	3,7	3,5	3,4	3,3	3,2	3,1	2,8	2,7	2,5
9	4,6	4,1	3,5	3,3	3,1	3,0	2,9	2,8	2,7	2,6	2,4	2,2
10	4,2	3,7	3,2	3,0	2,8	2,7	2,6	2,5	2,5	2,2	[illegible]	2,0
11	3,8	3,3	2,9	2,7	2,6	2,5	2,4	2,3	2,2	2,0	1,9	1,8
12	3,5	3,0	3,6	2,5	2,4	2,3	2,3	2,2	2,0	1,9	1,8	1,7
13	3,2	2,8	2,4	2,3	2,2	2,1	2,0	1,9	1,8	1,7	1,6	1,5
14	2,9	2,6	2,3	2,1	2,0	1,9	1,9	1,8	1,7	1,6	1,5	1,4
15	2,8	2,4	2,1	2,0	1,9	1,8	1,7	1,7	1,6	1,5	1,4	1,3
16	2,6	2,3	2,0	1,9	1,8	1,7	1,6	1,6	1,5	1,4	1,3	1,2
17	2,5	2,2	1,9	1,8	1,7	1,6	1,5	1,5	1,4	1,3	1,3	1,2
18	2,3	2,0	1,8	1,7	1,6	1,5	1,4	1,4	1,4	1,2	1,2	1,1
19	2,2	1,9	1,7	1,6	1,5	1,4	1,4	1,3	1,3	1,2	1,1	1,1
20	2,1	1,8	1,6	1,5	1,4	1,3	1,3	1,3	1,2	1,1	1,1	1,0
3 Б) Проходка с ручным трудом и отбойкой при помощи взрывчатых веществ.												
1,3	27	23	20	19	18	17	17	16	15	15	14	13
1,4	25	21	19	18	17	16	16	15	14	14	13	12
1,5	23	20	18	17	16	15	15	14	13	13	12	11
1,6	22	19	17	16	15	14	14	13	13	12	11	10
1,7	21	17	16	15	14	13	13	12	12	12	11	10
1,8	19	16	15	14	13	12	12	12	11	11	10	9
1,9	18	15	14	13	12	12	11	11	11	10	9	9
2,0	17	15	13	12	12	11	11	10	10	10	9	8
4 В) Проходка ручными работами.												
0,5	56	47	42	40	37	36	35	34	33	31	29	26
0,6	47	39	35	33	31	30	29	28	27	26	24	22
0,7	40	31	30	28	27	26	25	24	23	22	20	19
0,8	36	29	27	25	23	22	22	21	20	20	18	17
0,9	31	26	24	22	21	20	19	19	18	17	16	15
1,0	28	24	21	20	19	18	17	17	16	16	14	13
1,1	26	22	19	18	17	16	16	15	15	14	13	12
1,2	24	20	18	[illegible]	16	15	14	14	13	13	12	11
1,3	21	18	[illegible]	15	14	14	[illegible]	13	[illegible]	12	11	10
1,4	20	[illegible]	[illegible]	14	[illegible]	13	12	12	12	11	10	9
1,5	19	16	14	13	12	12	12	11	11	11	10	9
1,6	18	15	13	[illegible]	12	11	[illegible]	10	10	10	9	8
1,7	17	14	[illegible]	[illegible]	11	11	10	10	10	10	9	8
1,8	16	13	12	11	10	10	10	9	[illegible]	9	8	[illegible]
1,9	15	12	11	11	10	10	9	9	[illegible]	8	8	[illegible]
2,0	14	12	11	10	9	9	9	8	8	8	[illegible]	[illegible]

Table for transition from monthly face sinking speed to coefficient of hardness.

Sinking speed in meters

Key: (1) S in square meters; (2) A) Sinking with explosives without manual cut; (3) sinking with manual cut and breaking with explosives; (4) sinking by means of manual operations.

Paragraph 3. Summary of the above-mentioned. The next table presents a comparison of rock categories and their coefficients of hardness with various values that can serve for determination of these coefficients.

Comment. A symbol * means exclusively explosive operations which also refers to all numbers of the column located above; a symbol ** designates operations with a manual cut and breaking by means of explosives; a symbol *** means exclusively manual operations which refers also to numbers of the colums that are given below. The numbers are not shown for quicksands, because their sinking is very special and is connected with special attachments, fastening, etc.

Comment of the Scientific and Technical Council

Paragraph 1, p. 7. The newly introduced concept "hardness", related to the causes of destruction of bodies, which still lack comprehensive conclusions from the exact science, suffers from uncertainty and dimness, and the so-called "coefficient of hardness" lacks that relative meaning which it seems to have at the first sight. On the contrary, it has variable and also quite certain values. Its unit either is equal to 100 kg/cm^2 at compression, as it can be seen on p. 8, or 2.5 kg-m of work (p. 12), and it can hardly be used for characterization of many bodies which, according to the suggestion of the author, are easily characterized by the arbitrary selected stress. Thus, for example, it would be very difficult to characterize cast iron with its variable resistance to compression of about 8.5 - 8.8 ton/cm^2 and about 1.5-2 ton/cm^2 at stretching, pinewood which has 570 kg/cm^2 in crushing parallel to the fibers and 100-110 kg/cm^2 in crushing perpendicular to fibers; and sandwoods where their ration of temporary resistance at compression to temporary resistance at stretching is equal to 3 on the average or even greater.

Author's Responce

No. 2. The coefficient of hardness is an abstract number, a relationship of two named numbers. Therefore it can be both the ratio of kilograms per cm^2 at compression and ration of kg-m of work per 1 cm^3 at drilling, and ratio of the quantity of day labor, etc. Here we must compare homogenous values for different materials but not heterogenous for the same one.

Foe example, if we compare resistance to stretching along fibers of pinewood with that for an oakwood, as well as resistance across fibers for an oakwood, with the exactly the same for pinewood, but not the resistance along fibers with its resistance across fibers, or resistance of cast iron or sandstone ti compression with that to stretching which the Council probably mean by its comment. In general, as it was shown in the previous response, the method would be impossible if the proper comparisons produce striking difference, but, with the exception os some extraordinary cases, there is no such a difference.

Working Time and Efficiency

Paragraph 4. Working day and time distribution. 8-hours working day should be taken as one unit. The time distribution has to be as follows:

a) full time of a shift.................................. 8 hours

b) total working time (without descending to a mine, walking to the working place, leaving before the end of the shift after the day portion is done, walking back, etc.) .... 5 hours

c) pure working time (without breaks related to the nature of operations, exercising side operations, etc.) .... 3 hours.

This is the average norm for underground operations. Deviations are specially mentioned. We must assume for surface and shop operations:

a) full time of a shift .... 8 hours

b) total working time .... 8 hours

c) pure working time .... 5 hours.

Comment. If operation of surface workers are connected directly with operations of underground workers (for example, tommy bar operations while sinking a pit), the time distribution must be considered the same as that for underground operations.

Paragraph 5. Quantity of work. Quantity of work that a worker can make during 8-hour shift should be considered as:

a) for full shift .... 100.0 kg-m

b) for 1 sec. of total working time 5.5

c) for 1 sec. of pure working time 9.2

Категория. 1	Типичные породы. 2	f.	Способ работы. 3	[illegible] 4	[illegible] 5	[illegible] 6	[illegible] 7	[illegible] 8	[illegible] 9	Скорость [illegible] работки в [illegible]. 10
				Кг. 34	Куб. 35	Метр. 36	Кг. 34	Дюйм. 37	Дюйм. 37	Метр. 36
I	Кварцит 11	20	Взрывные работы 26	2000	200	0,40	2,00	—	—	1,9
II	Кварцевый порфир 12	15		1800	130	0,60	1,60	—	—	2,5
III	Гранит 13	10		1000	70	0,85	1,20	—	—	3,8
III a.	[illegible] 14	8		800	50	1,00	1,00	—	—	4,6
IV	Песчаник 15	6		600	35	1,40	0,90	—	—	6,3
IV a.	Песчаный сланец 16	5		500	25	1,70	0,80	—	—	7,0
V	Крепкий глинист. сланец 17	4		400	18	2,00	0,70	—	—	9,5
V a.	Сланцы 18	3		300	12	2,80	0,50	—	—	13
VI	Мягкий сланец, Антрацит. 19	2	Клиньями. 27	200	6,5	4,00	0,40	0,7	0,8	19* и 15**
VI a	Крепкий уголь, Щебенистый грунт 20	1,5	Кайлой и ломом. 28	—	—	6,00	0,35	0,5	0,6	25*, 21** и 17**
VII	Средний уголь, Глина. 21	1,2 / 1,0	Острой кайлой. 29					0,4	0,5	31
VII a.	Мягкий уголь, песчаная глина. 22	0,8	Широк. кайлой. 30					0,3	0,4	36
VIII	Чернозем 23	0,6	Заступом. 31					0,2	0,3	42
IX	Песок 24	0,5	Лопатой. 32	—				0,17	0,2	51
X	Плывун 25	0,3	Вычерпыванием. 33	—	—	—	—	1,3	—	—

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Table.

Key: (1) categories; (2) typical rocks; (3) method of operations; (4) crushing force per 1 cm^2; (5) work of drilling out 1 cm^3; (6) efficiency of drillers in a shift; (7) quantity of blasting gelatin per 1 m^2 at $s = 4\ m^2$; (8) number of navvies per 1 m^3; (9) number of drivers per 1 m^3 at $s = 4\ m^2$; (10) monthly speed of moving forward of a working; (11) quartzite; (12) quartz-porphyry; (13) granite; (14) limestone; (15) sandstone; (16) sandy shale; (17) hard clay shale; (18) slates; (19) soft slate, anhracite; (20) hard coal, rock debris soil; (21) medium coal, clay; (22) soft coal, sandy clay; (23) chernozem; (24) sand; (25) quicksand; (26) explosive operations; (27) by means of wedges; (28) pike and crow-bar; (29) sharp pike; (30) wide pike; (31) spade; (32) shovel; (33) scooping; (34) kg; (35) kg-m; (36) meters; (37) days.

The rotation speed (for example, rotation of a handle), given by the worker, is assumed as equal (per second) .... 0.7 m

Substantiation. Well-known investigations of Professor Rzhikha give the following average efficiency of a worker during 12-hour shift:

1. at dragging ....110,000 kg-m
2. at pumping out of water 117,000
3. on a pillar 119,551
4. at manual mining operations 120,500
5. at carrying load 122,168
6. at tamping 122.215
7. at moving soil 126,000
8. at windlass operation 136,428
9. at ascending 140,000
10. at operations with a lever 146,954

Average - 127,475 kg-m.

In accordance with the next paragraph, these numbers, upon transition to 8-hour day, accepted throughout this Regulation, these numbers must be reduced in the ratio of 10:8, i.e. mean efficiency should be taken as equal to

$$127{,}475 : (10 : 8) \quad 100{,}000 \text{ kg-m.}$$

Since according to the previous paragraph, the total working time is considered to be 5 hours, or 300 minutes, or 18,000 seconds, the per second work will be

$$100{,}000 : 18{,}000 = 5.5 \text{ kg-m.}$$

If we consider the pure working time when a worker is directly engaged in the main operation which we assume equal to 3 hours, or 180 minutes, or 10,800 seconds, then the per second work will be

$$100{,}000 : 10{,}800 = 9.2 \text{ kg-m.}$$

These numbers are used in the text of the paragraph.

Comment of Scientific and Technical Council

Paragraph 1, p. 14. In the Table, from which are derived coefficients of hardness aiming at demonstration of "undoubtedly obvious proportionality of rock relative hardness in various relations", there is total absence of data regarding resistances to tension which play such an important role in the rock resistance. In a mine, for example, they determine completely the height of the parabola arrow of the "vault" of rocks collapsing over the working, lense recoiling while opening of a face in elastic rocks, etc. According to the so-called second hypothesis of strength, which until recently has been officially accepted in the Railroad Department, tensile deformations are considered as the basic cause of destruction of bodies. Their presence in the Table would effect the final conclusions.

Author's Response

No.3. The data on resistance to tension are not included into the Table because they are not immediately found in various mining operations but they entered indirectly when rock extraction by means of a pike, explosions, etc. were mentioned.

Comment of the Council

Paragraphs 1 and 2, p. 10 and 14-28. In the methods of determining the coefficients of hardness are presented formulae whose origin has not been explained at all, which are new and are supposed to be trusted.

Author's Response

No. 4. All formulae are derived in corresponding paragraphs of the "Fixed Regulations".

Comment of the Council

Paragraph 1, p. 6. It is not indicated in the table to which tests the presented numbers belong: whether the tests were conducted along or across fibers, what was moisture level and other details needed for comparison.

Author's Response

No. 5. Experiments of Tethmayer are so commonly known that we, while using them for an example, did not want to overload the test with excessive details. We can say that resistance to stretching, compression and splitting-off was taken as average for the middle and lateral parts in the direction along the fibers, and resistance to bending - across the fibers.

Comment of the Council

Paragraph 1, p. 8. It is not indicated in what measures (over what area) is given the resistance of Sattel coal seam (198.5 kg and 75 kg) and value K_d = 1000 kg.

Author's Responce

No. 6. Must be clear from the text.

Paragraph 6. Transition to other length of a working day. If the working day is not 8 hours but of some other duration, efficiency of a worker is considered to be an average of the efficiency for normal 8-hour shift and a new one.

Example. Efficiency of a worker in 6-hour shift is equal to that which whould be for 1/2 (8 + 6) = 7 hours of work of a normal shift, i.e. it is equal to 7/8 of the previous one. By the same token, efficiency of 12-hour shift is equal to 1/2 (8 + 12) = 10 hours of a normal shift or 10/8, etc.

Substantiation. There are two extreme concepts. On one hand, a man is essentially a machine consuming daily certain amount of food and, in return, capable of releasing certain amount of energy in the form of conducted work. Therefore, if a man eats the same, he must be capable of performing the same work, regardless whether it is for 8, 6, or 10 hours. Hence, his efficiency (of course, within certain limits) is independent of durarion of the working day. On the other hand, a man always works with intensity that is the most convenient for him or, at least, always instinctively strive for this. Therefor, for example, for two hours of work he will make twice as much as for one hour, for three hours, three times more, etc.; his efficiency is directly proportional to duration of a working day. However, it is obvious that the truth is somewhere in between these two extreme concepts, because reduction of a working day results in a certain increase in possible working intensity, although not to such extent. Hence, we must better account work as it was indicated.

Here the mean arithmetic value can be substitutes with the mean geometrical, i.e., for example, instead of (8 + 6) : 2 we can take 8,6. Then the formula takes logarithmic form.

Paragraph 7. The number of working days in a month is assumed as 24. If the number of working days is different, the montly efficiency should be considered proportional to the number of days.

Example. Imagine that the drift sinking speed with the given coal at 24 days in a month and with one-shift work is equal to 20 running meters. Then at 18 working days it will be

(20 : 24). 18 = 15 running meters.

Substantiation. Since after the night rest, the efficiency of a worker is quite restored, there is no reasons to treat it differently.

Paragraph 8. When working at night shift, efficiency should be reduced by 25% of the norm

Example. At normal shift, coal entry advance is 0.8 running meters, but if working at night, the advance will be

0.75 X 0.8 = 0.6 running meter

Therefore, when work goes in two shifts, day and night, the total daily advance will be

0.8 + 0.6 = 1.4 running meter

Comment. The above decrease in efficiency should be taken into account only in the case when day and night work are paid differently being essentially identical. As for usual sinkings for two or three shifts, the above difference is not taken into account for the sake of simplicity.

Substantiation. The data of this "Fixed Regulations" are based completely on information obtained from practice. Therefore, the given numbers refer to the number of shifts that is the most common for this sinking. For example, in entry driving it is typical (for coal) that it would carried out in one shift, and the second shift deals with fastening and other auxiliary operations. For shaft sinking, operations in three shifts are normal, therefore the results of operations are divided equaly for three shifts. And so on. Therefore, there is no more need for separating day and night shifts, with the exception when operations are conducted by an unusual method.

Paragraph 9. In the case of urgent operations, conducted under extremely hard, dangerous, etc. conditions, the norms of the "Fixed Regulations" can be changed arbitrarily in accordance with given circumstances.

Example. Such, for example, are operations at coal fires, operations in grades with large influx of water, operatins at roof collapses, etc.

Paragraph 10. If similar work can be done by one person separately and by two persons together, then the speed of work of two persons together is considered by two thirds higher than in work of one person; efficiency of each of them is considered 1/6 lower. If the assistant is a worker of lower qualification, than speed is considered to increase by 50%, and the average decrease in productivity - by 25%.

Example. Imagine that efficiency of one-arm drilling in hard sandstone is 1.0 meter per shift. Then efficiency of two-arm drilling of two identical drillers, who can change places, will be 1.67 m.

Another example. Imagine that one blacksmith can adjust 100 drills during one shift. Them working with a hammerer, he will adjust 150 drills.

Comment. This rule is very approximate and can be applied only to the cases when both separate work and work of two persons together are equally acceptable.

Paragraph 11. If any operations is an accompanying one with another work, the efficiency of a worker supposed to be by 20-50% higher than that during separate conduction of this operation.

Example. Loading the dug soil to wheel barrows is an accompanying operation in digging soil if the worker, while digging, throuws the soil directly to the wheel barrow. Therefore, the number of workers needed for loading, should be 50% less than in the case of separate loading.

Paragraph 12. A table of daily salary of a worker in pre-war roubles that was taken into consideration while compiling the norms of this Regulation.

Drivers	1 rouble	60 kopeks
Drillers	1	60
Drillers at perforators	1	80
Coal cutters	1	60
Rock handlers	1	20
Underground haulers	1	20
Surface haulers	1	10
Bucket operators	1	50
Riders	1	20
Cager	1	20
Tommy bar operators	1	10
Unskilled workers	1	00
Fasteners	1	40
Carpenters	1	40
Masons	1	40
Stonecutters	1	60
Underground drawers	1	10
Surface hourse drivers	0	50
Hourses	1	50
Operators	2	00
Stokers	0	90
Locksmiths 1st class	2	00
2nd class	1	60
3rd class	1	20
Simple blacksmiths	1	50
Hammerers	1	00
Pump operators	1	80
Foremen	2	50

Comment. Multiplication of these numbers by the norms of the Regulation produces in that pay for work in pre-war roubles that was kept in mind while establishing the notms.

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