MEASUREMENT OF THE FATIGUE OF WORKERS IN A METAL MINE

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by

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Introduction

Complying with the request of the Tarô Mine of the Rasa Industrial Company, we have measured the fatigue of miners, in early spring of the year 1957. The mine is situated in the Mountains of Iwate Prefecture (northern part of Honshu Island) about four miles from the seashore (the Pacific Ocean). It produces ores which contain mainly cupper. It is a small mine with about three hundred workers in all.

The kinds of their work may be classified in seven:
(1) rock drilling, (2) tramming, (3) setting timber up, (4) chuting, (5) tending cage, (6) operating battery locomotive, (7) tippling.

The process of mining is as follows:

(1) At first, with a rock-drill the rock-driller drills the bore on the face of the pit, fills the explosives into the hole and blasts the rock.

(2) The trammer collects the ores with a hand scraper and puts them into an iron tray, and then stuffs them into the mine tub. Pushing the mine tub he carries them to the chute and drops the ores into the chute.

(3) The timberman sets up timbers and supports the face in order to protect the face from crumbling.

(4) The chute man, dragging out the bottom cover of the chute, lets ores flow out into the tub.

(5) The cage tender, driving the elevator of the shaft, elevates or lowers the tub to the holizontal adit level and hands them to battery locomotive operator.

(6) The battery locomotive operator combines several tubs loaded fully with ores and drives them out of the mine.

(7) The tipplerman pushes the tubs into the tippler and rotating them once round, empties them one by one into the storage yard for ores.

The process of mining goes on almost in such a manner. We wanted to measure the degree of fatigue by the seven different types of work. In this

mine the work loading was surveyed through C. F. F. measurement, Body Weight measurement, Subjecive Symptoms Survey, Relative Metabolic Rate (R. M. R.) and Work Density (actual work percentage). We have taken charge of C. F. F. and body-weight. The C. F. F. value is measured as a symptom of psychological function and the body weight as that of body function. We have wanted to judge the miner's fatigue through these measurements as well as the other surveys. Subjective Symptom Survey, R. M. R., and Actual Work Percentage were measured by Mr. Akira Kunimi, Chief in Safety Preserving Board, Tarô Mine of the Rasa Industrial Company. We are grateful to the Director of the company, all the staff of Mining Board of the company for their kindness and to the workers who have served as subjects in our research.

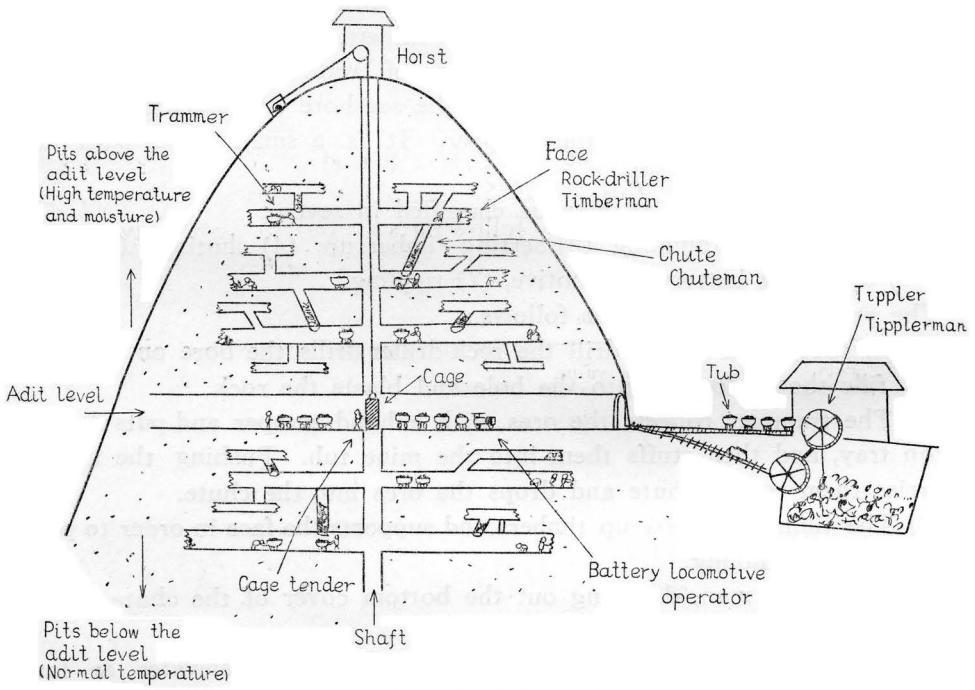

Fig. 1. Longitudinal section of Tarô mine and illustration of mine terms

I. Measurement of C. F. F.

The Critical Flicker Frequency (C.F.F.) indicates the excitement level of visual system including central nervous system. As it is well-known, the resolving power which discriminates the flicker, oscillates sensitively according to the condition of organism and it shows the change of the organism's perceptual

function accurately. Therefore, when one wants to see the change of perceptual function through work, this method of measurement is now generally used[1][2].

In the industrial labour, the C. F. F. value is at the highest excitation level in the morning and as one goes on with his work, the C. F. F. value falls. This curve shows a little recovery after a noon recess, but in the afternoon it falls down again. The greater the labour loading, the greater is the falling of curve in the afternoon. Such an oscillation during one day is acknowledged in general. Accordingly, the commonest way is to measure the difference between the value in the early morning when a worker gets to work and the value in the evening when he is going home.

In our investigation of fatigue of the mine-workers, we chose C. F. F. as a measure of the changes of psychological function. The direct object of our research is, as described above, to find the different degrees of fatigue by seven kinds of work.

Procedure

(1) Date

The measurement was carried out over a period of seven days extending from Feb. 28th to March 6th of 1957. The first day was assigned to a preliminary experimentation and the following six days to main experiments.

(2) The preliminary experiment

Table 1. Results of preliminary experiment

Subjects	Pre-work value	Post-work value	Dif.
T	38.1 cps	41.9 cps	−3.8
St	36.3	39.9	−3.6
Sc	39.1	42.0	−2.9
O	37.7	38.9	−1.2
Sg	39.1	36.7	+1.4
G	43.6	42.5	+1.1
Sn	38.1	40.3	−2.2
Tk	36.6	36.6	0.0
Mean			−1.4
Tg	38.9	40.0	−1.1
K	41.5	41.5	0.0
Ta	38.4	40.0	−1.6
N	37.9	39.0	−1.1
S	33.4	36.1	−2.7
Te	39.6	39.8	−0.2
Mean			−1.1

In the first day, we carried out a preliminary test to prepare ourselves for the following main experiments. We employed eight rock-drillers and six timbermen as *Ss* and measured pre-work value and post-work value at appointed time respectively. Table 1 shows the results. In this Table, the figures are the final average values of ascending threshold value and descending threshold value which were measured three times respectively. From the results of a preliminary experiment, the following was found:

(i) The difference between pre-work value and post-work value came out as we had expected, and, in the average, the rock-driller showed a greater falling than the timberman.

(ii) There was little scattering, and high stability was found in six judged values at each measurement. This is perhaps due to the fact that the workers of this mine have so often taken psychological tests that they are accustomed to them. Accordingly, we thought two times each test, four times in all, good enough for the measurement of ascending threshold and descending threshold.

(iii) Further, we gained many suggestions with regard to how to instruct or how to carry out the experiments, etc.

(3) The main experiments

Using these results of preliminary examinations as a basis, we formed plans for main experiments.

(a) Subjects

The total number was 175. They were classified in seven kinds of work. The selection and the constitution of these groups of *Ss* were made as follows:

(i) As the C.F.F. has sensitive responsiveness to age differences, it was necessary to limit the range of *Ss'* ages to a certain extent. But these miners were not in large numbers, and of various ages, so that we had to limit the age ranging from 25 to 42.

(ii) To compare the day shift with the night shift was also one of the problems for us to solve. We tried to distribute the subjects as well as possible to compare the two shifts. But, after all, in facing of the practical difficulty, we could take no accurate measurement of night shift.

(iii) In order to confirm week effects, it was necessary to measure each *S* every day, but as it was practically impossible to do this, each subject was measured for two days. And we endeavoured to allot these two day measurements of each *S* to each week day.

(iv) Moreover, we had to select almost the same numbers of *Ss* from each kind of work. But as absolutely few workers were engaged in some kinds of work, we filled up this vacancy by repeating the measurements of the same

S over two times.

(v) Finally, we must mention the conditions by pit. For, the pits below the adit level of this mine were kept at normal atmospheric temperature, while in the pits above the adit level the temperature was very high and in some places it amounted to about 50°C. Such a temperature difference was, without doubt, an important factor influencing the fatigue, so that we attached the Ss equally to both pits.

According to such conditions just described, we have distributed Ss as shown in the Table 2. This Table shows both the distribution of Ss and the variables included in our experiments.

Table 2. Distribution of Ss according to kinds of work, difference of pits and days

	Pits	March 1	March 2	March 3	March 4	March 5	March 6	Sum
Rock-driller	A	1	2	4	2	3	1	13 } 38
	B	6	5	3	5	2	4	25 }
Timberman	A	1	0	7	2	4	0	14 } 42
	B	7	7	1	8	0	5	28 }
Trammer	A	3	0 (1)	3 (5)	3	4	3	16 } 36
	B	3	1 (3)	4 (6)	6	6	0	20 }
Chuteman	A	1	3 (0)	3	0	2	2	11 } 19
	B	2	0 (1)	3	0	1	2	8 }
Locomotive operator	A	0	2	2	1	0	2	7 } 14
	B	1	1	3	1	0	1	7 }
Cage tender		3	2	3 (5)	0	0	5	13
Tipplerman		0	6	1 (3)	2	1	3	13
Sum		28	29 (5)	37(19)	30	23	28	175 (24)

A: Pits above the adit level
B: Pits below the adit level
( ): Night shift

(b) Apparatus and the method of measurement

Apparatus: Sector type of flicker fusion (C. F. F.) measurement apparatus made by the Takei Company Ltd. was used. If we turn round a knob, and variate the cycle of A. C. current which is transmitted to a synchronous motor, then we can regulate the sector's rotation. The scale was indicated in "c. p. s."

The method of measurement: We measured ascending threshold and descending threshold two times respectively. The measurement was carried out at each time just before the workers enter into the pits and just after their coming

out of them. That is, the pre-work value of the day shift was measured between 7.00 a.m. and 8.00 a.m., the post-work value between 3.30 p.m. and 4.30 p.m. As for the night shift, we measured between 3.00 p.m., and 4.00 p.m., between 10.30 p.m. and 11.00 p.m. respectively. By the way, it may be said in this connection that the labour time of this mine in question was eight-hour labour system, the day shift being from 7.00 a.m. to 3.00 p.m. and the night shift from 3.00 p.m. to 11.00 p.m. Each shift had one hour's rest time for a meal. We have counted C. F. F. decrement percentage as follows:

C. F. F. decrement percentage

$$= \frac{\text{(Post-work value)} - \text{(Pre-work value)}}{\text{(Pre-work value)}} \times 100$$

Reviewing the measurement thus carried out, one had to pay attention to the fact that all of *Ss* were out of control of *E* except at the time of the measurement done twice a day. Accordingly, we asked each *S* questions concerning the duration of sleeping in the previous night, drinking, special house-affaires and further about body condition etc. Particularly with regard to the night shift who stayed at home by about 2.00 p.m., we had to give careful consideration about the points just described above. As is often the case with the labour in the mine, their work happens to be subject to change. Therefore, we ascertained it in measuring post-work value. We were obliged to except 18 *Ss* from our research, or we had to change the type of work. Table 3 shows the figures which have already been modified.

Results and Interpretations

(1) Distribution of *Ss*

Before describing the results of our measurement, we must make sure whether the distribution of *Ss* (shown in Table 2) was appropriate or not.

(i) May it safely be said that the *Ss* were assigned with about equal ratio to the pits above the adit level and the ones below the adit level on each day of measurement? To ascertain this point, in case of five occupations by pits, i. e., the rock-driller, the timberman, the trammer, the chuteman and the cage tender, we calculated theoretical value of distributions for each day of measurement by pits, and administrated the χ^2 test. As the result the null hypothesis should be abandoned except for in the timberman of the pits above the adit level ($\chi^2 = 16.2$, $\chi^2_5(0.05) = 11.07$). This shows that the distribution of *Ss* for each day on each job assigned with about equal ratio. Therefore, it proved to be good to test the differences between pits by pooling *Ss* of five occupations by pits.

(ii) For each day of measurement, were the *Ss* engaged seven kinds of work assigned equally? The numbers of *Ss* distributed according to sorts of work

by pooling the pits above the adit level and the pits below the adit level is shown in Table 3.

Table 3. Distribution of *Ss*

	March 1	March 2	March 3	March 4	March 5	March 6	Sum	χ^2
Rock-driller	7	7	7	7	5	5	38	—
Timberman	8	7	8	10	4	5	42	3.4
Trammer	6	1	7	9	10	3	36	10.0
Chuteman	1	3	5	2	0	3	14	5.9
Locomotive operator	0	6	1	2	1	3	13	6.6
Cage tender	3	3	6	0	3	4	19	3.6
Tipplerman	3	2	3	0	0	5	13	8.4

As we can see from this Table, all of the χ^2-values show that the null hypothesis should be abandoned. Therefore, there seems to be no question with regard to the distribution of *Ss* for each day of measurements.

(2) Test on the difference between pits

The average values gained by pooling each result of 61 *Ss* of the pits above the adit level and of 88 *Ss* of the pits below the adit level are as follows:

Pits above the adit level ····· − 2.28 %
Pits below the adit level ····· ····· − 2.13 %

That is, though we can find a slightly larger numerical value in decrement percentage for pits above the adit level where the temperature is high, the difference between both values is not statistically significant ($t = 0.242$). It may be adequate to think that, perhaps, owing to the fact that the practical conditions of labour were more complicated, the difference of temperature has no direct effect upon C.F.F. For example, it may be considered it is partly due to the fact that the workers in the faces where the temperature was high, took a rest more often.

(3) Variation of C. F. F. during the six working days

The average value calculated by pooling decrement of all *Ss* for each day is shown in Table 4 and Fig. 2. Here we want the readers to note that the first day of measurement falls on the second day of working in the mine. If we carry out an analysis of variance, we can find that there is a significant

Table 4. Changes of the decrement of C. F. F. during six days

Days	1	2	3	4	5	6
ΣX	−83.2	−59.6	−12.1	−42.2	−92.0	−73.4
N	28	29	37	30	23	28
$\bar{X}$	−2.97	−2.55	−0.33	−1.41	−4.00	−2.62

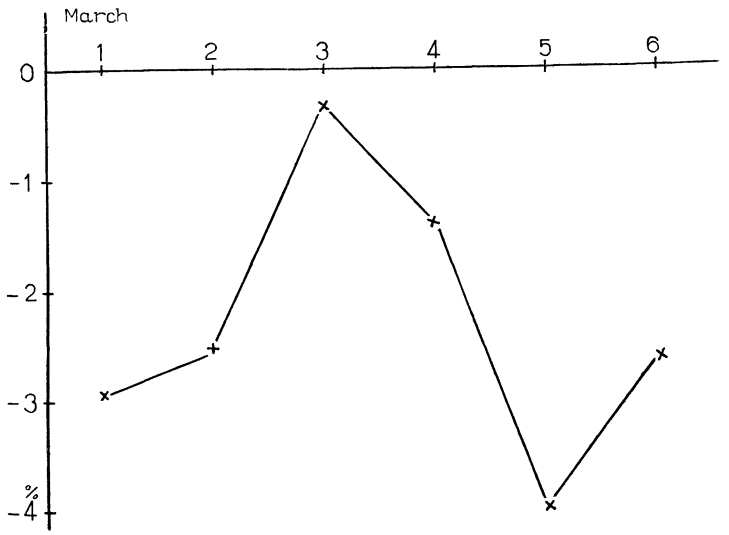

Fig. 2. Variations of C. F. F. decrements in different days

Table 5. Results of analysis of variance

Source	SS	df	ms	F
Between days	233.5491	5	46.7098	3.835*
Error	2058.3214	169	12.1794	
Total	2291.8705	174		

* F^{5}_{125} (0.01) = 3.17

difference at 1 % level (Table 5). In interpreting these results, it must be taken into consideration that the decrement we have used is of a relative value. Accordingly, variation of C. F. F. decrement during the days of measurement do not represent the shift of coordinates on the C. F. F. scale.

We can see in the Fig. 2 decrement degree of C. F. F. becomes lower from the 2nd (March 1) toward the 3rd and the 4th working day. On the following days it increases gradually, and on the last working day it decreases again. The decline of the curve on the final day may be explained in terms of a

week-end effect, while it is somewhat difficult to explain the decline on the 3-rd and 4th working days. We may understand this decline as an effect of adjustment to work or so called effect of warming up.

(4) Difference of C. F. F. by seven kinds of work

Table 6 shows the average value of C. F. F. decrement by seven occupa-

Table 6. Means of decrement of C. F. F. by kinds of work

	Rock-driller	Timber-man	Cage tender	Trammer	Battery locomotive operator	Chuteman	Tippler-man
ΣX	−142.2	−94.8	−23.4	−49.6	−18.2	−20.8	−10.3
N	38	42	13	36	14	19	13
$\bar{X}$	−3.79	−2.26	−1.80	−1.38	−1.30	−1.10	−0.79

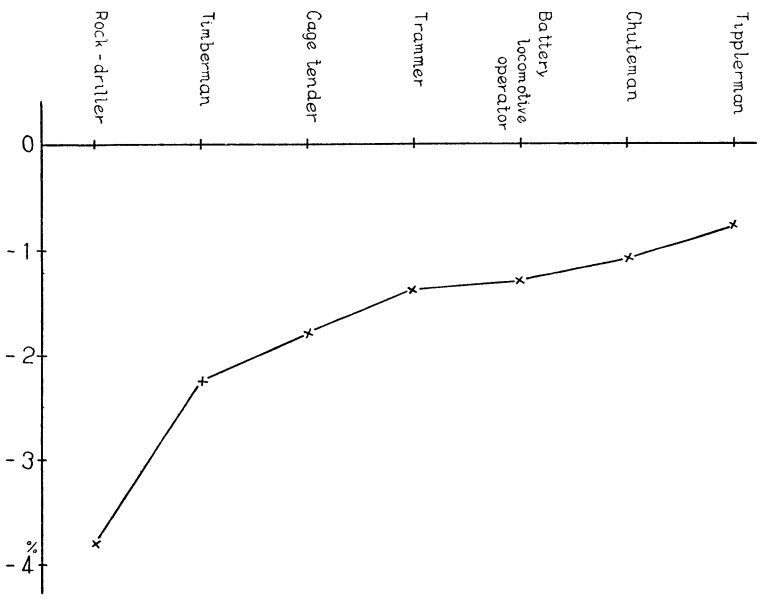

Fig. 3. C. F. F. decrements of seven kinds of work

tions and Fig. 3 also shows it figuratively. As can be seen from Fig. 3 the rock-driller and the timberman showed the greatest decrement as compared with other kinds of work. There was no great difference among the trammer, the battery locomotive operator and the chuteman.

The least decrement was shown by the tipplerman. Table 7 shows the results of analysis of variance (test 1) on this difference of seven kinds of work. As the F value is only a little smaller than the coded score at 5 %

Table 7. Results of analysis of variance for difference among seven kinds of work (test 1)

Source	SS	df	ms	F
Between works	143.2714	6	23.8786	1.681 *
Error	2386.3132	168	14.2042	
Total	2529.5846	174		

* F^{6}_{200} (0.05) = 2.14

level, it can not be said that there is a significant difference among seven kinds of work. But since the decrements of rock-driller and timberman are considerably greater than those of others, as shown in Fig. 3, no differences in the statistical test appear to be due to the decrement similarity among three other types of work. Then, by pooling the similar three classes of work, the trammer, the chuteman and the battery locomotive operator, and then between this group and other 4 kinds of work, the rock-driller, the timberman, the cage tender and the tipplerman, i. e., among 5 groups in all, we tried again the analysis of variance (test 2). The result is shown in Table 8. This treatment

Table 8. Results of analysis of variance for difference between five kinds of work (test 2)

Source	SS	df	ms	F
Between works	142.7842	4	35.6961	2.542 *
Error	2386.8004	170	14.0400	
Total	2529.5846	174		

* F^{4}_{150} (0.05) = 2.43

resulted in giving significant difference at 5 % level. Further, let us consider why such a significant difference came out. We tried t-test for each combination of five groups described above (test 3). From this it was found that there was no difference between, the group of chuteman, battery locomotive operator and trammer and the group of cage tender, and between the former group of three classes of work and the group of tipplerman, and between the rock-driller and the timberman ($t_0 = 0.44$, $t_{60}(0.05) = 2.00$; $t_0 = 1.09$, $t_{80}(0.05) = 1.99$; $t_0 = 1.395$, $t_{60}(0.05) = 2.00$ respectively). We may therefore conclude that the significant difference in test 2 has come out from the difference among the classes of work other than the above mentioned combination of them. About the difference among various classes of work in the decrement of C. F. F., we have attained the following sure result that there is a clear difference between the group of rock-driller and timberman and the group of the other five sorts

of work.

Further, on the extent of fatigue in the sorts of work which have been regarded as showing no C. F. F. difference, we shall discuss later again together with decrease in body weight.

(5) On the night shift

With regard to the night shift, owing to various circumstances as we have mentioned in the beginning, we could not collect enough data to be able to analyze by various tests. Surveying the limited data which we could collect, we can see that the change of C. F. F. is almost in the direction of "+". That is, post-work value is larger than pre-work values. Presumably this results may have come from the characteristics of the changes of C. F. F. in day and night time. In general, the changing curve of C. F. F. in day time indicates some dropping down at 3 00 p. m. and afterwards it tends to ascend slightly. As we have measured the pre-work value of night shift at 3. 00 p. m., it is certain that the difference between pre-work value and post-work value in the second (night) shift differs from the difference in the first shift in its sense.

To our regret, we have little knowledge in this respect, so we can not gain a relevant answer with regard to the second shift.

II. Measurement of body weight decrement

In the first section we have dealt with C. F. F. as a measure of changes of psychological functions through fatigue. As an index of body functions we attempted also to measure body weight decrement.

Physical labour makes one's breath hard, and fascilitates perspiration to keep his temperature constant. Accordingly, hard physical labour results in increasing amount of loss of water from body through breath and perspiration. Moreover, the higher atmospheric temperature and humidity in working environment, the more may become the amount of water loss. In other words, physical labour comes to set the organism to a physiological task to control his temperature, so the water metabolism must be one of the important factors of fatigue. In this sense, we have considered body weight decrement as a measure which is most likely to show some physiological loadings of labour and somatic fatigue accompanied by it. The body weight decrement is primarily due to the intensity of the water metabolism, as represented in the following equation.

Post-work body weight decrement
= (loss of water through perspiration, breathing and urination
− intake of water and foods) + (weight of O_2 and CO_2 in

expiration − weight of O_2 and CO_2 in aspiration)

(1) Method of the measurement

The measurement was carried out at the same time with that of the C. F. F., and *Ss* and the other experimental conditions were all the same as in the case of C. F. F. measurement. We calibrated the pre-work values of the body weight at each given time on each experimental day by body weight meter. Numerical values thus obtained were transformed to the rate of decrement in percentage according to the following equation.

Rate of body weight decrement

$$= \frac{\text{Post-work value} - \text{Pre-work value}}{\text{Pre-work value}} \times 100$$

(2) Results

(i) Difference between the pits (above the adit level and below it): The difference between the pits is a difference in atmospheric temperatures. We could not find this difference in C. F. F. Now, may we find it on the body weight decrement? If it depends mainly on the water metabolism of organism, we can expect that the difference may come out. Means of body weight decrement of all *Ss* in both pits were as follows:

Pits above the adit level	− 1.29 %
Pits below the adit level	− 0.97 %

Certainly, the mean value of the pits above the adit level was smaller than that of the other. However, *t*-value falls between 0.10 and 0.05 level, which indicates no significant difference. So we could not draw any clear conclusions from this result statistically. It should be noted that though atmospheric temperature in the pits above the adit level was generally higher than in the pits below the adit level, there existed some faces in which the temperature was not so high. If we take account of this point, it will be permitted to conclude that the difference of atmospheric temperature has some effects on the body weight decrements. Accordingly these workers' fatigue may be greater than that of the others.

(ii) Differences among the days: The means of all *Ss*' body weight decrements on each day are shown in Table 9 and Fig. 4. It may be seen that there is an

Table 9. Body weight decrements in different days

Days	March 1	2	3	4	5	6
Body weight decrements	−0.87	−0.70	−1.24	−1.41	−1.43	−0.75 %

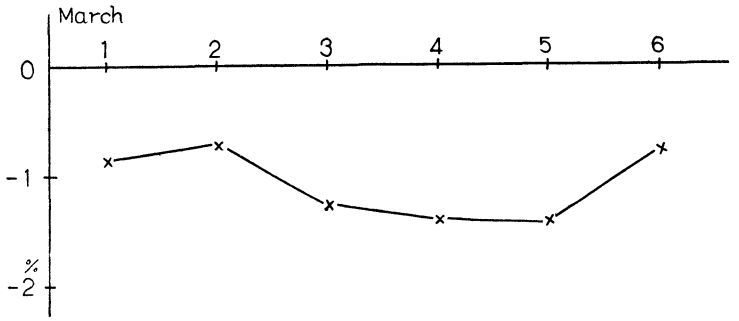

Fig. 4. Body weight decrement in different days

obvious difference among the days without reference to statistical test. The decrements are increasing with days and decrease reversely on the last day. We realize immediately that the curve represents a similar trend with the C. F. F. curve (Fig. 2). But on the 3rd day (the 4th working day), the body weight decrement increases, contrary to the C. F. F. The last rising of the curve, as was the case with the C. F. F., is due to the week-end effect. On the other hand, the 4th day's (the 5th working day) rise of the curve suggests some effects in a sense of adaptation of labour as in the case of the C. F. F. curve and it is simillar to that of the lst day (the 2nd working day). But, to

Table 10. Averaged body weight decrements by seven kinds of work

Kinds of work	Trammer	Timberman	Cage tender	Rock-driller	Tippleman	Chuteman	Locomotive operator
Decrements	−1.77	−1.08	−1.60	−0.96	−0.74	−0.55	−0.54 %

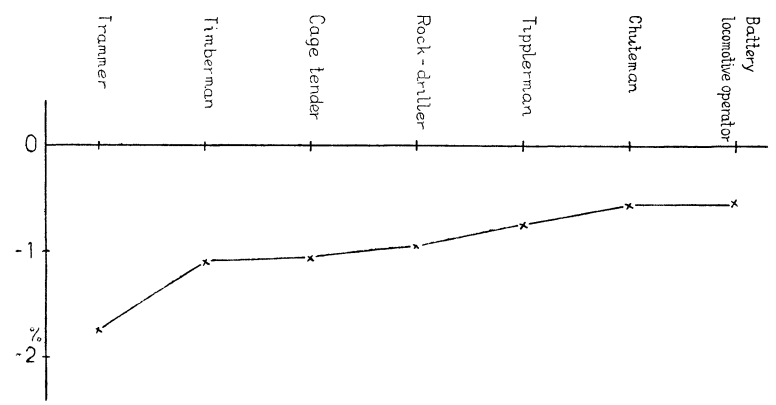

Fig. 5. Body weight decrement of seven kinds of work

comprehend these results, we must compare them with those of the decrement of the lst working day.

(iii) Differences among the kinds of work: The mean values for each kind of work are listed and plotted in Table 10 and Fig. 5. An analysis of variance for these values (Table 11) reveals a significant difference at 0.01 level.

Table 11. Results of analysis of variance for differences of body weight decrements among seven kinds of work

Source	SS	df	ms	F
Between works	2514	6	419	3.81*
Error	18397	168	110	
Total	20911	174		

* $F^{6}_{150}(0.01)=2.92$

In order to know rank order of decrement, we carried out a further analysis of combinations of each kind of work. The result indicated that the order of the degree of decrements which was proved to be significantly different from each other was as follows ; (1) trammer (decreased at most), (2) timberman, cage tender and rock-driller, (3) tipplerman and (4) chuteman and battery locomotive operator (decreased at least).

(iv) Correlation between C. F. F. and body weight decrement: If we assume that the C. F. F. and the body weight decrement should reflect psychological and physical fatigue respectively, coefficient of correlation between two measurements will have an important key for interpretation of our data. However, it became clear that the coefficients of correlation could not be found between them. From these, it follows that psychological fatigue does not always increase with bodily fatigue.

III. Discussion and comparison with other researches

Now, we have found that there is no correlation between decrement of the C. F. F. and the body weight decrement. Let us study this incongruence of two measurement results from the wider viewpoint.

(1) At first, let us view the difference between pits. Although the decrement of the high temperature pits was slightly more than that of the other, but the difference in the C. F. F. was not significant. On the other hand, for the body weight decrement the difference between pits came near to the significant level barely ($0.10>p>0.05$). However, the difference of the effect of atmospheric temperatures on labour or worker should be recognized, since the dif-

ference between pits lies in the expected direction on both measures. Why did the difference between workers under different atmospheric temperatures not differ so clearly in our measurements ? About it, we hold the following opinions. (a) One opinion is that apart from the body weight decrement, C. F. F. is not sensitive to such factor as atmospheric temprature. (b) The other is that atmospheric temperature varies with each face in the both pits, and in the pits above the adit level, in addition to this, in the faces where it was high atmospheric temperature, workers took rests very often somewhere else in cooler face. So far as our investigation is concerned, we regard the latter as appropriate.

(2) A second problem is a difference in measures by days. We found a similar trend on the curves of both measures taken each day ; the week-end effect appeared in both curves. But a difference was also observed. On the C. F. F. curve, a tendency was pointed out which was interpreted as some effects like a kind of an adaptation to labour, that is, rising of the curve on the 2nd and 3rd experimental days. But we could not find the same effects in the curve of body weight decrement. It appears to us that it is because the warming up effect is not so much a bodily effect as a psychological effect mainly.

(3) The most important question is that the coefficient of correlation between the C. F. F. measure and the body weight decrement was not positive. The r on all Ss is -0.01, almost equal to zero. Apparently it seems to be strange, but further consideration will show that this apparent contradiction is reasonable. Now it would be assumed that the C. F. F. would not represent sufficiently the psychological fatigue, and that the body weight decrement might not represent the physical labour loading. Therefore, in order to ascertain the validity of the both measures used in our research, let us compare those with the results of some other researches. About one month later, Kunimi in the mine carried out several studies ; that is, the R. M. R. and the Actual Work Density on each kind of works[3]. Table 12 shows these results. In this Table the trammer is at top rank on the R. M. R. Besides, he shows nearest percentage to standard level on the Actual Work Density in comparison with other kind of work, that is to say, the labour amount of the trammer is the greatest among the others. This result corresponds exactly to the first rank of his body weight decrement. Further, if we compare the labour amount and body weight decrement of different classes of work with each other, their rank orders correspond well to each other on the whole. Therefore, we might say that the body weight decrement is a relatively good measure representing the intensity of the physical labour.

Next, let us compare the results of the C. F. F. with those of the Subjective

Table 12. Results of R. M. R., Actual Work Density, Standard Work Density and report percentage of Subjective Neural Symptom in seven workers

Workers	R. M. R.	Actual Work Density	Standerd Work Density	Report % of Subjective Neural Symptom
Rock-driller	2.03	70 %	85 %	32.3 %
Timberman	1.63	54	75	24.7
Trammer	2.32	73	77	5.1
Chuteman	2.23	84	97	24.2
Cage tender	1.65	70	97	8.1
Btatery locomot. operator	0.95	82	100	0.0
Tipplerman	1.27	47	75	5.1

Symptom Survey which are also reported by Kunimi. It is remarkable that the more appeals of subjective symptom of psychological fatigue was reported, the more decrements of the C. F. F. was observed ($r = +0.64$). On the contrary, a coefficient of correlation between the body weight decrement and the Subjective Symptom Survey is only -0.07. While the C. F. F. decreases relating to psychological work loadings, the body weight decrement has a less close relation with them. This may be interpreted as indicating that the C. F. F. varies sensitively with psychological work.

In facts, a detailed inspection of contents of each kind of work shows more clearly the validity of the above interpretation. Tasks of the rock-driller, timberman and cage tender require of course not only physical labour of them, but at the same time some intellectual or nervous tension also. Therefore, it is reasonable that the decrements of the C. F. F. of these classes of work are much greater than that of those engaged in the other works. On the other hand, the labour of trammer is most intensive indeed, but it is rather simple physical labour and many intellectual techniques are not required of him. This will be the reasons why the trammer shows the greatest value of the body weight decrement, on the contrary his rank is the 4th in the decrements of the C. F. F. Yet the trammers are relatively young, so that the decrement is rather small.

As stated above, our results can be explained without contradiction as far as we have dealt with the measure alone of the C. F. F. and of the body weight decrement. Because the r between these two measures is almost equal to zero, it follows that the C. F. F. measure and the body weight decrement reflect respectively each one of the two different functions. That is to say, it may be permitted to conclude that the C. F. F. indicates mental work loadings and

the body weight decrement represents physical labour loadings. Thus, it is a mere hypothesis to assume that the psychological functions and the physical functions will vary with the intercorrelate. Our results show that the psychological works and the physical labours may affect the organisms in a different manner respectively.

The coefficient of correlation between the C. F. F. measures and body weight decrements was -0.01, but this value is calculated by pooling all *Ss*' measures. Now, if we acount the correlation between the mean values of the different classes of work, then we get $r = +0.22$. That is, we find a slightly positive correlation between them. This correlation may be easily comprehended, if we overlook their rank order ; that is, if we overlook the curves of Fig. 3 and 5, it is easily observed that the groups of rock-driller and timberman show much more decrements in both the figures, while the groups of tipplerman, chuteman and battery locomotive operator belong to a lower part of the curves. These indicate that they have correlations in some measure between the decrement of C. F. F. and the body weight decrement. In other words, we should not ignore that the fatigue of psychological aspects also depends on the fatigue of physical aspect to some degree.

If we consider as just described, it was shown that it is not impossible to understand the relation of the C. F. F. measure with the body weight decrement. From the above, our conclusions will follow : physical labour of the trammer is the hardest, yet much brain tension is not required of him. Therefore, the changes of psychological functions of the trammer seem slight. The rock-driller and the timberman of whom intellectual work as well as physical labour is required, show much more psychological fatigue, and their body weight decrements are also relatively great but less than that of the trammer. On the other hand, the tipplerman, the chuteman and the battery locomotive operator have rather less fatigue on both the psychological and physical aspects. Generally speaking, these results suggest that if we attempt to deal with fatigue, not only one of the organism's functions but several functions should be measured also at the same time.

(4) Kunimi, A. also investigated accident occurring ratio on each kind of work during last five years in the mine[4]. When we compare his results with ours, an interesting fact can be observed (Table 13). The fact is that the occupations to which accidents are liable to occur at higher rate are those which are ranked at upper portion on the C. F. F. decrement, body weight decrement and R. M. R. This finding offers the suggestion that fatigue is closely related to the cause of accident occurring. But the trammer, the rock-driller and the timberman are always exposed to the danger of accidents in the faces objectively. Consequently, we can not arrive at a general conclusion as to whether

Table 13. Comparison of our resuluts with accident occurring ratio in the mine

Workers	% of accident occurring	R. M. R.	Decrement of C. F. F.	Decrement of body weight
Trammer	0.155	2.03	−1.38 %	−1.77 %
Rock-driller	0.094	1.63	−3.79	−0.96
Timberman	0.087	2.32	−2.26	−1.08
Tipplerman	0.013	1.27	−0.79	−0.74
Locomot. operator	0.008	0.95	−1.30	−0.54
Cage tender	0.007	1.65	−1.80	−1.06
Chuteman	0.004	2.23	−1.10	−0.55

there is correlation between fatigue and accident or not.

(5) Lastly, we are surprised to see that the decrements of C. F. F. are so small, though the labour in the mine is so intensive. It is generally said that interpretations of fatigue are difficult if the decrement of C. F. F. is less than 10 %. In our research, the mean of the decrement was only about 1 %. One may interprete this result indicates that though physical labour is hard, it does not lower the C. F. F. value so much. Lest our apparatus should be somewhat out of order, we calibrated the cycle but could not detect any defect.

Summary and Conclusions

Early in March, 1957, we carried out measurements of fatigue through the decrement of C. F. F. value and body weight decrement of 175 miners of Tarô Mine in Iwate Prefecture, Northern Japan. The experimental variables considered were the difference among seven kinds of work (i. e., rock-driller, timberman, trammer, chuteman, cage tender, tipplerman and battery locomotive operator), the difference between pits (atmospheric temperature difference), and the difference among six days when the measurement was carried out. The index of these variables was degrees of decrement which were represented by perecentage of the difference between pre-work value and post-work value to the former. These variables underwent some statistical tests and considerations.

The results were summarized as follows:

(1) Difference between the pits (difference of atmospheric temperature)

In the C. F. F. decrement, no significant difference was proved statistically. Also in the body weight decrement, as t-value was slightly insufficient for the significant level of 5 %, the difference was not supported by the statistical test.

Yet the two decrements were greater in the pits above the adit level (high temperature) than in those below the adit level. Therefore it could not be denied that difference of atmospheric temperature was one of the important factors.

(2) Difference among the days

Both the C. F. F. decrement and the body weight decrement became greater toward week-end, but on the last day, decreases were found on the contrary. This decrease may be regarded as week-end effect. One remarkable difference between these two measures was that the C. F. F. decrement tends to decrease in the middle of week, while the body weight decrement did not indicate such a clear tendency. We identified this effect reflected in the C. F. F. decrement with the warming-up-effect or adaptation effect to the work.

(3) Difference among kinds of work

The order in greatness of the C. F. F. decrement was ; (1) rock-driller who showed the largest decrement, (2) timberman, (3) cage tender, (4) trammer, (5) battery locomotive operator, (6) chuteman and (7) tipplerman whose decrement was the smallest. On the other hand, as for the body weight decrement order, we find the rank as follows ; (1) trammer, (2) timberman, (3) cage tender, (4) rock-driller, (5) tipplerman, (6) chuteman and (7) battery locomotive operator. As to the C. F. F. decrement, a statistically significant difference was obtained, between the group of rock-driller and timberman and the group of the rest. As for the body weight decrement, a statistically significant difference was ranked among the following four groups, in the order of the greatness of decrement ; (1) trammer, (2) group of timberman, cage tender and rock-driller, (3) tipplerman and (4) group of chuteman and battery locomotive operator.

Because of no significant correlation between the C. F. F. decrement and the body weight decrement, we examined these results in relation with R. M. R., Actual Work Density and Subjective Symptom Survey. Then we could ascertain the reliability of C. F. F. decrement and body weight decrement. These considerations lead to conclusions that the C. F. F. value appeared to vary in correspondence with fatigue in psychological function in the main and the body weight decrement seemingly corresponded with the fatigue in physical function in the main. From the changes of these two functions we inferred the characteristics of difference between the kinds of work as follows ; physical labour of the trammer is most intensive but does not require so much intellectual technique, so that his fatigue in psychological function was not so great. The rock-driller and the timberman have relatively great physical fatigue but indicated much more decrement of C. F. F. This was seemingly due to the fact that

psychological tension as well as physical labour was required of them. On the other hand, the degree of fatigue of the tipplerman, the chuteman and the battery locomotive operator was not so intensive in psychological as well as in physical functions.

(4) At last, we stated some considerations with respect to the fatigue of miners, in relation with the accident occurrence rate in the mine.

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Le mesurage de la fatigue des ouvriers dans un mine du metal

Résumé

Au commencement du Marche, 1957, nous avons exécuté des mesurages de la fatigue par la diminution de la valeur de CFF (Critical Flicker Frequency) et du poids de corps, quant aux 175 mineurs de Tarô Mine dans Iwate Préfecture, dans le Nord du Japon.

Les quantités variables considérées dans cette recherch ont été la différence entre sept genres des travaux [c'est-à-dire, le roche-foreur, le joueur des bennes, le joueur des poutres en bois (cadre porteur), le chuteman, c'est-à-dire l'ouvrier minier qui fait des minerais glisser le long du puits pour en rouler de la galerie plus haute à celle au niveau de la surface terrienne et en charge les wagonettes, le joueur de cage de puits, l'operateur de locomotive aux accumulateurs électriques, le joueur de tippler, c'est-à-dire, l'appareil pour décharger la benne roulante des minerais sur la place accumulante à la roulage extérieure du puits], la différence entre les galibots (la différence entre la température de l'air dans le puits au-desus de la galerie et celle dans le puits au-desous de la galerie) et la différence entre six jours où les mesurages son tété exécutés. L'indice de ces variables a été le degré de diminution que nous avons représenté par

pourcentage de la différence de la valeur de pre-travail et celle de post-travail pour la premiére. Ces variables se sont été soumits aux quelques épreuves statistiques et concidérations.

Ces résultats en résumé sont les suivantes :

(1) Différence enter les galibots (différence par la température de l'air).

Dans la diminution de CFF, aucune différence significative n'a pas été éprouvée statistiquement enter les galibots. Aussi que, dans la diminution de poids de corps, la différence se n'est pas soutenue par l'éprouve statistique, puisque la valeur de t n'a pas un peu suffisante à arriver au niveau 5 %.

Malgré tout, toutes les deux diminutions out été plus grandes dans le puits au-desus de la galerie (il a de la température plus haute) que dans le puits au-desous de celle. Par conséquence, on ne saurait nier que la différence de température de l'air fut un des facteurs importants.

(2) Différence enter jours.

Toutes les deux indices de diminution de la valeur de CFF et celle de poids du corps ont devenu plus grandes sur la fin de semaine, mais au contraire, dans la dernier jour de semaine, on se trouve que les indices décroissent. Cette décroissement est peut-etre regardée comme l'effet de la fin de semaine. Il est une des différences remarquables pour deux mesure que, dans la curve de la diminution de CFF, on se trouve une tandance de décroissement dans la milieu de semaine, c'est-à-dire, dans les troisième ou quatrième jour ouvrable, tandis que diminution du poids de corps n'a pas indiqué telle tendance clairement. Nous avons identifié cet effet qui s'est reflété dans le diminutions de CFF avec l'effet de "warming-up" ou l'effet d'adaptation au travail.

(3) Différence entre les genres des travaux.

L'ordre dans grandeur de diminution de CFF est la suivante : (1) les roche-foreurs qui ont montré la plus grande diminution, (2) les joueurs de poutres (3) les opérateurs de cage de puits, (4) les joueurs des bennes, (5) les opérateurs de locomotive aux accumulateurs électriques, (6) les chutemen et (7) les joueurs de tippler, dont la diminution a été la plus petiti. De l'autre côté, quant à l'order de diminution du poids de corps, nous nous trouvons le rang comme la suivante : (1) les joueurs des bennes, (2) les joueurs de poutre en bois, (3) les joueurs de cage de puits, (4) les roche-foreurs, (5) les joueurs de tippler, (6) les chutemen et (7) les opérateurs de locomotive aux accumulateurs életriques. A l'égard de la diminution de CFF, la différence significative statistiquement a été obtenue entre la groupe de roche-foreurs et pouteurs et la groupe des autres sortes de travail. Quant à la diminution du poids de corps, la différence signi-

ficative statistiquement a été éprouvée entre les quatre groupes suivantes : dans l'ordre de grandeur de la diminution, (1) le joueur de benne, (2) la groupe des cadre porteurs, joueurs de cage de puits et roche-foreur, (3) joueur de tippler et (4) la groupe des chuteman et operateurs de locomotive aux accumulateurs électriques.

Parce qu'il n'y a pas aucune correlation significative entre les diminution de CFF et poids, nous avons examiné ces résultats en relation de RMR, densité de travail actuel et l'étude sur symptôme subjetif. Alors nous pouvons constater la sécurité de la diminution de CFF et poids de corps. De ces considérations, il s'ensuit les conclusions que la valeur de CFF a semblé changer en correspondance avec la fatigue dans la fonction psychologique en grand partie, et aussi que la diminution de poids de corps correspondre à la fatigue dans la fonction physipue principalement. Des changes de ces deux fonctions, nous inférions les caractéristiques de différence entre les genres de travail comme la suivante : le travail physique de joueur de benne est la plus intensive, mais ne demande pas tant des techniques intellectuels, c'est pourquoi sa fatigue dans la fonction psychologique de roche-foreur et cadre porteur est plus grande relativement, mais ils montraient bien plus diminution de CFF. Il paraît que c'est causé par la fait qu'ils étaient demandés la tension psychologique aussi que la travail physique.

De l'autre côté, la degré de la fatigue du joueur de tippler, du chuteman et de l'opérateur de locomotive aux accumulateurs électriques n'était pas telle intensive dans les fonctions psychologiques aussi que dans les fonctions physiques.

(4) En dernier lieu, nous avons donné quelpue considérations en relation à la raison d'événement d'accident dans cette mine.

Messung der Ermüdung des Mienenarbeiters

Zusammenfassung

Um den Ermüdungsgrad zu untersuchen, führten wir Anfang März, 1957, eine Woche lang die Messung vom Abnahmegrad des Flimmern-Häufigkeitsprozentsatzes (CFF) und des Körpergewichts über die 175 Mienenarbeiter vom Tarô-Berg in der Iwate-Präfektur, Nord-Japan durch. Die bei diesem Versuch betrachteten Variablen waren die Differenzen unter 7 Arten der Arbeit (Bohrer, Fördermann, Stempelsetzer, Sammelbehälter, Förderkorbempfänger, Gruben-Geleise-Wagenführer und Ablader), die Differenzen der verschiedenen Mienengänge (Wärmegrad-Differenz zwischen den Mienengängen über der Bodenebene und der Schacht), und die Differenzen unter den Messungs-Tagen. Jeder Mes-

sungswert zeigt den anf den Wert vor der Arbeit bezogenen Prozentsatz der Differenzen zwischen den Werten vor und nach der Arbeit. Diese Prozentzahlen haben wir mit den verschiedenen Arten der Verifikation der statistischen Hypothese analysiert und in Betracht gezogen. Dieses Resultat fassen wir zusammen:

1) Unterschiede zwischen den verschiedenen Mienengängen (Wärmegrad-Differenz)

Es erfolgte keine statistisch sinnvolle Differenz beim Abnahmegrad des CFF-Werts. Auch beim Abnahmegrad des Körpergewichts wurde keine statistische sinnvolle Differenzen gefunden. Doch waren beide Messungs-Werte grösser beim höheren Wärmegrad, und bei den Arbeitern in den Mienengängen über der Bodenebene grösser als bei sonstigen Mienenarbeitern, also konnten wir nicht umhin, die Wärmegrad-Differenz als noch eine der wichtgsten Faktoren zu erkennen.

2) Unterschiede unter den Messungs-Tagen

Beide Abnahmegrade des CFF-Werts und des Körpergewichts nahmen immer mehr gegen den letzten Arbeitstag zu, aber nahmen am letzten Arbeitstag ab. Der letzte Arbeitstag ist als eine Wochenende-Wirkung zu betrachten. Ein grosser Unterschied zeigte sich zwischen beiden Messungswerten: dass der Abnahmegrad des CFF-Werts am dritten und vierten Arbeitstag, d. h., ungefähr in der Mitte der Woche, abnahm, während beim Abnahmegrad des Körpergewichts diese Tendenz nicht in Erscheinung trat. Wir deuten diese beim Abnahmegrad des CFF-Werts gefundene Wirkung als die des im-besten-Zuge-seienden Zustandes.

3) Unterschied unter den Arbeitsarten

Die Rangordnung des Abnahmegrades des CFF-Werts ist, von dem Grössten nach den Kleinsten gezählt: (1) Bohrer, (2) Stempelsetzer, (3) Förderkorbempfänger, (4) Fördermann, (5) Gruben-Geleise-Wagenführer, (6) Sammerlbehälter, und (7) Ablader.

Im Gegenteil haben wir beim Abnahmegrad des Körpergewichts die folgende Rangordnung gewonnen; (1) Fördermann, (2) Stempelsetzer, (3) Förderkorbempfänger, (4) Bohrer, (5) Ablader, (6) Sammelbehälter, und (7) Gruben-Geleise-Wagenführer. Statistisch sinnvolle Differenz wurde, beim Abnahmegrad des CFF-Werts, zwischen der Gruppe von Bohrern, Stempelsetzern und den übrigen Arbeitsgruppen gefunden. Andereseits haben wir beim Abnahmegrad des Körpergewichts, solche Differenz zwischen 4 Gruppen, d.h., (1) Fördermann, (2) Stempelsetzer, Förderkorbempfänger, Bohrer, (3) Ablader, (4) Sammelbehälter, Gruben-Geleise-Wagenführer.

Weil dabei keine Korrelation zwischen den CFF-Werten und dem Körpergewicht zu beobachten war, betrachteten wir diese Werte im Vergleich

mit dem relativen Stoffwechselprozentsatz (R. M .R.), dem Wirklich-Arbeitsprozentsatz und mit der Untersuchung über die subjektiv bemerkte Symptome. Und wir haben also die Zuverlässigkeit der CFF-Werte und Körpergewichtsmessung geprüft. Auf Grunde dieser Betrachtung darf man wohl annehmen, dass sich CFF-Werte im Grossen und Ganzen der geistigen Arbeit entsprechend verändern und dass die Körpergewicht vielmehr der körperlichen Ermüdung entspricht.

Infolgedessen können wir aus diesen beiden funktionellen Veränderungen zum Schluss gelangen: Obwohl die Arbeit des Fördermanns am härtesten ist, ist seine geistige Ermüdung dagegen nicht so gross. Körperliche Ermüdung des Bohrers und Stempelsetzers ist verhältmässig gross, aber der Abnahmegrad von dem CFF-Wert ist noch grösser. Dieses muss sich vielleicht aus ihrem Bedürfnisse der geistigen Spannung neben der körperlichen Arbeit folgern.

Anderseits ist der Ermüdungsgrad des Abladers, Sammelbehälters und Gruben-Geleise-Wagenführers geistig-körperlich nicht so gross.

4) Schliesslich haben wir noch die Miene-Ermüdung betrachtet, und ihr Verhältnis zum Unfall-Entstehungsprozent erklärt.