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On an analysis of Bus driver's Flicker Values (1)

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There are a number of methods for measuring the fatigue because the measurement of this in the working hours is useful for analyzing the factors of fatigue and for the utilization of the labor management.

In this paper, the fatigue of bus drivers who have experience of various number of years in some bus company is measured by the flicker and these values are analyzed by X^2 test or sign test and its control limit is determined. These are contributed to find a daily variation and to estimate the fatigue capacity, the degree of skill and what factors have influence on points which oversteps the limit line.

It was found in this study that the limit line gets lower as the year of experience increases and the flicker values decrease in the forenoon.

§ 1. Introduction

From the medical standpoint, labor physiology and labor hygienics etc. play the principal roles in the industrial fatigue and for the measurement of the fatigue various methods have been devised.

The measurement of flicker values is one method to determine the degree of the fatigue and this method are investigated by several authors[1-3].

In an attempt to see whether or not flicker values would serve as the criterion for the capacity and the skill of subjects, a siries of the experiment was carried out on a certain group of bus drivers and the trend of fatigue is studied on the basis of flicker test. The control limit of the range in individual or in a group was estimated. The method which determines the control limit is same as that in the manufacturing processes. And the differences in the flicker values in the forenoon and the afternoon are analyzed by X^2-test and sign-test.

As the result it has been demonstrated that our methods would serve sufficiently for analyzing the data on fatigue as well as determining their capacity and skill.

§ 2. Mehtods of analysis

In estimating and testing the fatigue and the level of skill which will constitute the back ground of fatigue, it is natural to expect that there will be a slowly growing trend with slight intermittent daily changes because the subject is a physiological living body.

Even though the mean value is an important criterion for such study but in order to obtain other evaluations, it is desirable to observe ranges between the maximum and minimum of daily flicker values. The notations are as follows.

$$\bar{R}_i = \frac{1}{n}\sum_{j=1}^{n} R_{ij}$$

$$\bar{R} = \frac{1}{mn}\sum_{j=1}^{m}\sum_{i=1}^{n} R_{ij} = \frac{1}{m}\sum_{j=1}^{m} \bar{R}_i$$

where

$R_{ij} = \max_k A_{ijk} - \min_k A_{ijk}$,

A_{ijk}: flicker value of each individual,
i; denotes the subject number, j; the test day and k; the measurement number.
$i = 1, 2, \cdots\cdots, m$, $j = 1, 2, \cdots\cdots, n$,
$k = 1, 2, \cdots\cdots, r$,
R_i: the true range for the subject number i, $\bar{R}$: the true range for the entire group.
R: Range, FF: flicker value,

1) The Control Limit for the Range

The control limit uses in the following is that of level 5%. In generally, the control limit is caluculated by the following formula:

$$A_1(r)\,\bar{R}_i \leqq R_i \leqq A_2(r)\,\bar{R}_i$$

$$A_1(r)\,\bar{R} \leqq R \leqq A_2(r)\,\bar{R}.$$

In this case constants $A_i(r)\,(i=1,2)$ are obtained from the table when the level and the measure-

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ment number are given. To that values various authors are given different values. The table in "primer to sampling method"[4] is used in this paper.

The value on the right hand side of the equation denotes the upper control limit (UCL) and that on the left the lower control limit (LCL).

2) Analysis of differences in the forenoon and the afternoon by X^2-test or by sign test

n_1 is the number of j such that

$A_{ij}^k < 0$ for $j = 1, 2, \cdots, m$

where $A_{ij}^k = A_{ijk+1} - A_{ijk}$.

Then in si_n test calculations are as follows: when m is smaller than 100, the limit n_α of n_1 is given by the table for level α[5] and if $n \geq 100$, then we take an intiger such

that $$n_\alpha < \frac{n-1}{2} - k\sqrt{n+1}$$

and $\frac{n-1}{2} - k\sqrt{n+1} - n_\alpha$ is minimum

where k is constant and determines as α is given.

If $n_1 \leq n_\alpha$, there exists some differences between k group and k + 1 group.

In X^2-test, it is hypothesized that there is no difference between k group and k + 1 group. Then we obtain

$$X_0^2 = \frac{(2n^1 - n)^2}{n}$$

if $X_0^2 > X_\alpha^2(1)$, so the hypothesis is rejected[5].

§ 3. Subject and method

Bus drivers of a certain bus company who invariably report to the office after the morming hour duty are subjects of this study.

These drivers have experiences of 10 months to 5 years in that company and in the age of 24 to 35 years old, all being male. This group is composed of two persons with experience of less than one year, four with that of one to four years and two with over four years. From the method of analysis it is necessary to carry out the experiment continuously over a fairly long period. Therefore the unit is set by one month and measurements are taken three times a day. It is impossible to carry out the measurement on mass at the same time because of the difference in duty hour of individuals. So hour ranges in which almost all measurements are included, are set up. The first range is between 6.30 and 8.30, the second range between 11.30 and 14.00 and the third between 17.00 and 20.00. The first measurements are taken after roll call and working check (20 minutes) to avoid the influence of commutation. Data which measured in the afternoon on account of working hour, was used only for analyzing variations in the forenoon and the afternoon but not for calculating the control limit. However it seems to be a loss of informations. If the test and estimation can be used in such a case, it becomes possible to carry out the more precise analysis by shortening the hour range.

This experiment was carried cut the period of the latter part of August to the biginning of September, 1966, and futher for some drivers about one week in the middle of October in order to see whether the control limit at that time can be used.

The flicker values in this study is shown in Fig 1.

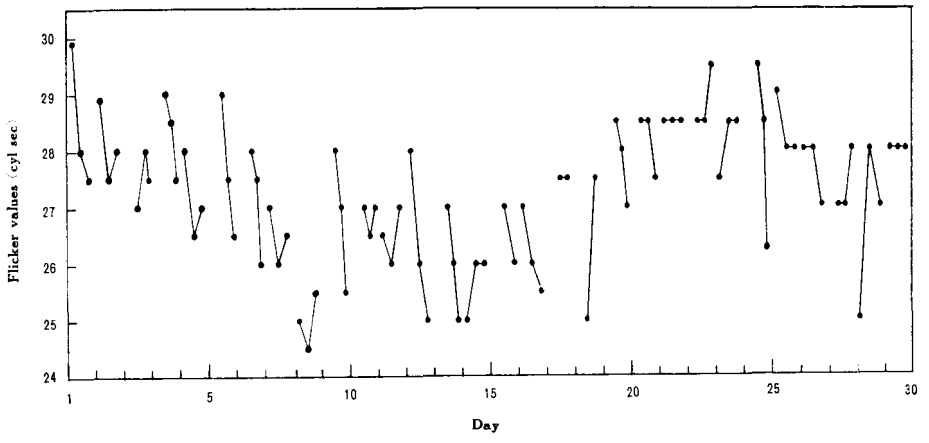

Fig 1. A month's flcker values of B_3

§ 4. Result and Discussion

1) On two drivers A_1, A_2, with experience less than one year.

Upper control limit (UCL) of A_1 is 6.9 C/S being very high and variations are about 2.5 times as much as those of others. As for variations in the forenoon and the afternoon, there is a decreasing tendency of F-F values in both hours.

UCL of A_2 is 3.0 and the daily variations of F-F are almost within the limit line but it is somewhat greater than that of others with experience over one year. As for the variations in the forenoon and the afternoon, it was found by X^2 test and sign test at the level of significance 5% that F-F decreases in the forenoon. Namely F-F in the second measurment is lower than that of the first. In the afternoon the numbers of increment are nearly equal to the numbers of decriment. (Fig 2,)

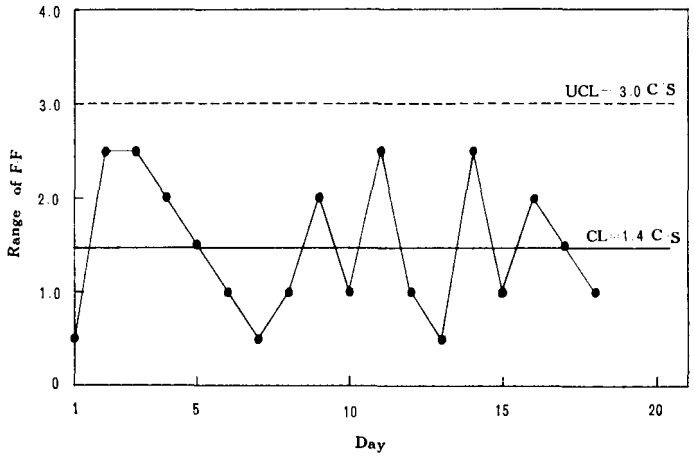

Fig 2. Control chart of A_2

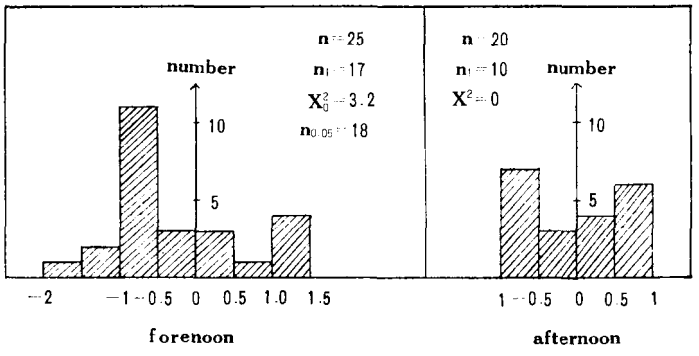

Fig 2'. Variations in the forenoon and the afternoon of B_1

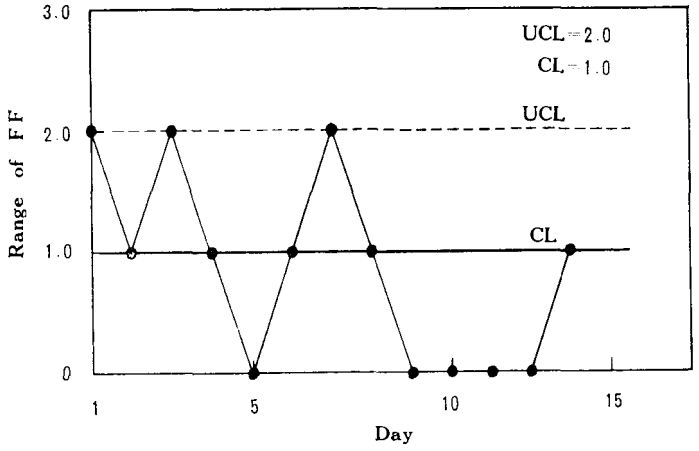

Fig 3. Control chart of B_2

2) On three drivers B_1, B_2, B_3, with experience over one year.

UCL of B_1 is 2.3 and variations of F-F are controled same as A_2. It was found by X^2 test at the level of 10% and by sign test at the level of 20% that F-F decreases in the forenoon but there are no apreciable differences at the level of 5%. (Fig 2)

B_2 is seemed to be superior both in his personal character and skill at driving, so he becomes the subject in this experiment. His UCL is 2.0, being markedly smaller than others and on the changes of F-F values in the forenoon and the afternoon hours, it was found by X^2 test at the level of 5% and by sign test at the level of 10% that his F-F values of both hours increse or don't change. Looknig at the cases for three points on UCL, it happend once on a rainy day, once a closing hour at 20: 00 and rainy day and once day after a holiday. (Fig 3)

B_3 is a veteran with experience of five years in the company. His UCL is 2.8 which is nearly equal to UCL of the group showing in the following. The numbers of increment are nearly equal to that of decriment in the forenoon and afternoon. F-F values which were measured about a week in the next month are listed in the

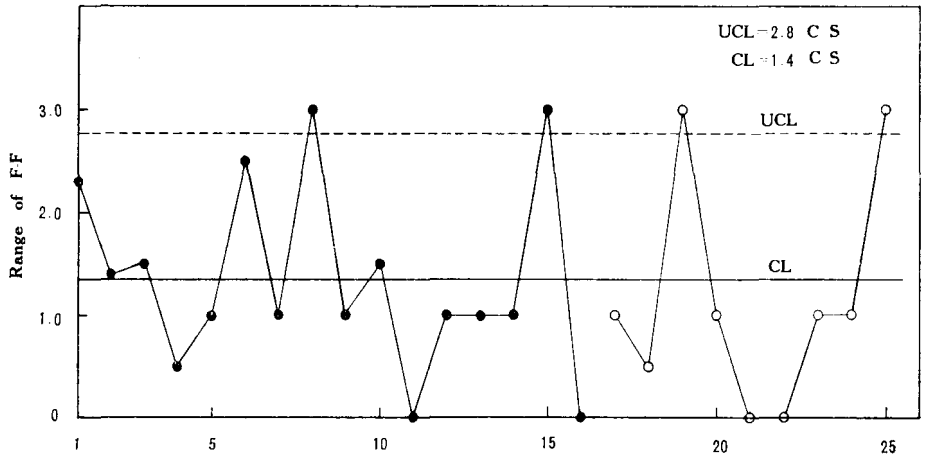

Fig 4. Control chart of B_3 and Ranges after a month

control chart. Then it was found that the weather and the conditions under which they worked have had a considerable influence on the F-F values. In other words, the values on rainy days and on the late closing hour's days overstep the limit line during about a week. (Fig 4)

3) The UCL of the group except for A_1 is estimated to be 2.6. Then it was found that UCL of B_1, B_2 and B_3 are equal to or less than this and that UCL of A_1 and A_2 are larger than this. As for the variations of all in the forenoon and the afternoon, it was said by X^2- and sign test at the level of 5% that F-F values decrease in the forenoon, while there is hardly any discernible change in the afternoon as individual data showed. Therefore in the forenoon, drivers have a tendency to be tired with their works and this will be one factor of traffic accidents. The UCL which was estimated with F-F values of veterans seems to serve sufficiently as a standard criterion for determining qualitatively the labor fatigue. (Table 1)

Table 1. The variations in the forenoon and the afternoon

	FORENOON				AFTERNOON			
SUB-JECT	N	N_1	X^2_0	SIGN	N	N_1	X^2_0	SIGN
A_1	10	8	3.6	9	8	6	2.0	8
A^2	20	19	16.2**	15*	20	11	0.2	15
B_1	25	17	3.2	18	20	10	0.0	15
B_2	14	3	4.6**	2	13	2	6.2**	2*
B_3	21	12	0.4	16	29	16	0.3	11
group	89	59	9.4**	55*	90	45	0.0	55

*: The hypothesis rejects at the level of 5%
**: The hypothesis rejects at the level of 1%

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