CHAPTER III

METHODOLOGY

Subjects

Twelve workers performing the final inspection of mini transistors, an electronics part, were requested to fill up a questionnaire, CERGO questionnaire, to understand if they were in unusual condition to work.

For mental fatigue, three workers were used as subjects, with a mean age of 24 years and a mean experience of 7 months. The average height and weight were 152±4 centimeters (mean = 153 cm.) and 44±4 kilograms (mean = 44.33 kg.), respectively. Prior to participating in the experiment, their vision were examined. Only the normal were required to avoid performance differences.

To measure cumulative load of trapezius muscles and heart rate, one subject of the three-workers was participated as volunteering subject.

Equipment

1. Critical Flicker Fusion Frequency Apparatus.
2. Reaction Time Apparatus.
3. Self-scaling Questionnaire.
4. CERGO Questionnaire.
5. Electromyographic Recorder (ME-3000).
6. Electronic Pulse Massager.
7. Heart Rater Monitor (Polar Sport Tester)
8. Strain Gauge Dynamometer
9. Stop Watch.
10. Ortho-Rater.
11. Lux-meter.
12. Sound Level Meter.
13. Thermohydrographic Recorder.

Methods

To assess mental fatigue of inspection task along working time, objective and subjective methods were both used. The values for objective methods were critical flicker fusion frequency, reaction time, work output, and sleeping hours on the day before testing. For subjective method, a self-scaling questionnaire was used to assess the subjective feelings of fatigue. All were done before and after work. The muscle fatigue and heart rate during work were assessed by measuring electromyogram and heart rate in the begin and at the end of week. Statistical analysis would be conducted using a computerized statistical package available. The problem of prioritizing contributing factors with respect to their relative importance to mental fatigue can be formulated as a problem of multiple objective decision-making. Since this study does not concern with whether the determined factors effect to the mental fatigue but also with how strongly they belong to it, a fuzzy decision-making approach is more appropiate than a proabilistic approach (Zadeh, 1965). Even though conventional technique, such as factorial design, is able to be used for studying th effects of two or more factors, it is unsuited for dealing with the problems involving vague or fuzzy in nature like this study. Therefore, fuzzy set theory would be applied to determine the importance of the factors to the dependent variables.

Factors Influenced the Experiment

In the experiment, three factors were focused : shift work, rest allowance, and paced work.

1. Shift Work

Working in shift was a pattern of behavior that was unnatural and against 'time-keeping system' of human beings. It causes discomfort to man, lowers efficiency, and increases mental fatigue. In this study, night shift and morning shift were interesting.

2. Rest Allowance

In working activity, fatigue reduces the functional capacity. To eliminate fatigue, man needs rest during work to recover the functional potency. In this study, we were interested in alternative rest pauses as 1) rest time equals in all pauses (4 rest times of 5 minutes after 1 hour of work, 20 minutes rest in total or R1), and 2) rest time equals in all pause except the last pause, and the rest time was extended (2 rest times of 5 minutes after two hours of work and after 50 minutes of work after meal, and 1 rest time of 10 minutes after the next 50 minutes of work -- 20 minutes rest in total or R2).

3. Paced Work

The existing paced-inspection situation is mostly self paced which there is no external machine-generated rate but is paced by management objectives. The workers can vary the rate of work over the work cycle to meet these objectives. Otherwise, it is assumed that using machine-paced in the control of the process and in eliminating the variability between inspectors and/or shifts are more efficient than self-paced. For this reason, management prefer to introduce machine-paced.

Both of the rest pause mentioned above will be compared with the allowance calculated by conventional method that is supplied by Peter Steele and Partners from United Kingdom (International Labour Organization, 1981).

Procedures

1. Data Collection Methods

1.1 Critical Flicker Fusion Frequency and Reaction Time

Subjects were interviewed before test to find out their health. If they got any problems, the test would not be done. The measurement of mental fatigue were done two times a day, before and after working. Prior to start the experiment, subjects were trained to use flicker fusion frequency and reaction time apparatus to eliminate the learning effect that may influence to the data. Each subject was trained to use those equipment 2 times a day for 3 days.

1.1.1 Measurement Method

1.1.1.1 Critical Flicker Fusion Frequency (CFF)

There were two kinds of CFF measurement, increasing and decreasing the frequency of intermittent light. As sitting, the decreasing the frequency of intermittent light. As sitting, the subjects were asked to press the button with their dexterous hand while looking at the intermittent red light on the white screen of the equipment. For increasing of the intermittent light frequency, the subjects were supposed to release the button immediately as the flickering light was constant. The test was done 5 times with 5 seconds break after each. Then the intermittent light would be changed to the decrease of frequency, that the intermittent light changed from constant to flickering, and the test were done in the same way.

1.1.1.2 Reaction Time

The reaction time measurement were recorded with two kinds of stimuli, light stimulus and sound stimulus. During the test, the subjects remained in a sitting position with the forefinger of their dexterous hand on a button response box. As fast as possible, the subjects would push on the button when any stimulus were shown. The reaction time shown on the display would be recorded. The measurement was done 10 times for each stimulus.

1.2 Self-scaling Questionnaire on Fatigue

In order to know how the subjects feel, two sets of questionnaire were used. Firstly, it was about personal data and experience of work. And secondly, it was the bipolar scaling questionnaire that used to estimate fatigue. This questionnaire consisted of 7 eleven-point scales setting up according to the principle of opposing predicates : bored-interested, dull-ready for action, tired-refreshed, weak-strong, exhausted-vigorous, sleepy-awake, and tense-relaxed. The subjects would characterize their own state by judging their own feeling at a particular moment on the proposed scale. The scale went from -5 to 5 , where number 5 represented the extremely feeling and zero represented normal situation.

1.3 Electromyography

In order to assess local fatigue signs, bipolar surfaced EMG was used to measure the cumulative load of the neck and shoulder muscles during working period. Two muscles were selected for the EMG-recordings. the upper and the lower part of the trapezius muscle (Figure 3.1). The measurement was done throughout working day of the first working day of seek and the last working day of the same week.

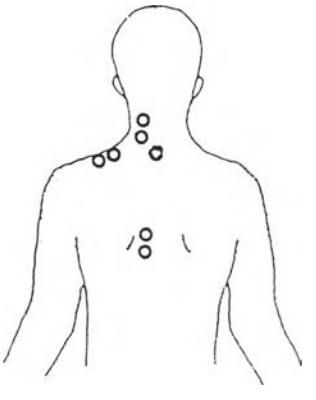


Figure 3.1 The attached position of surface electrode for EMG measurement

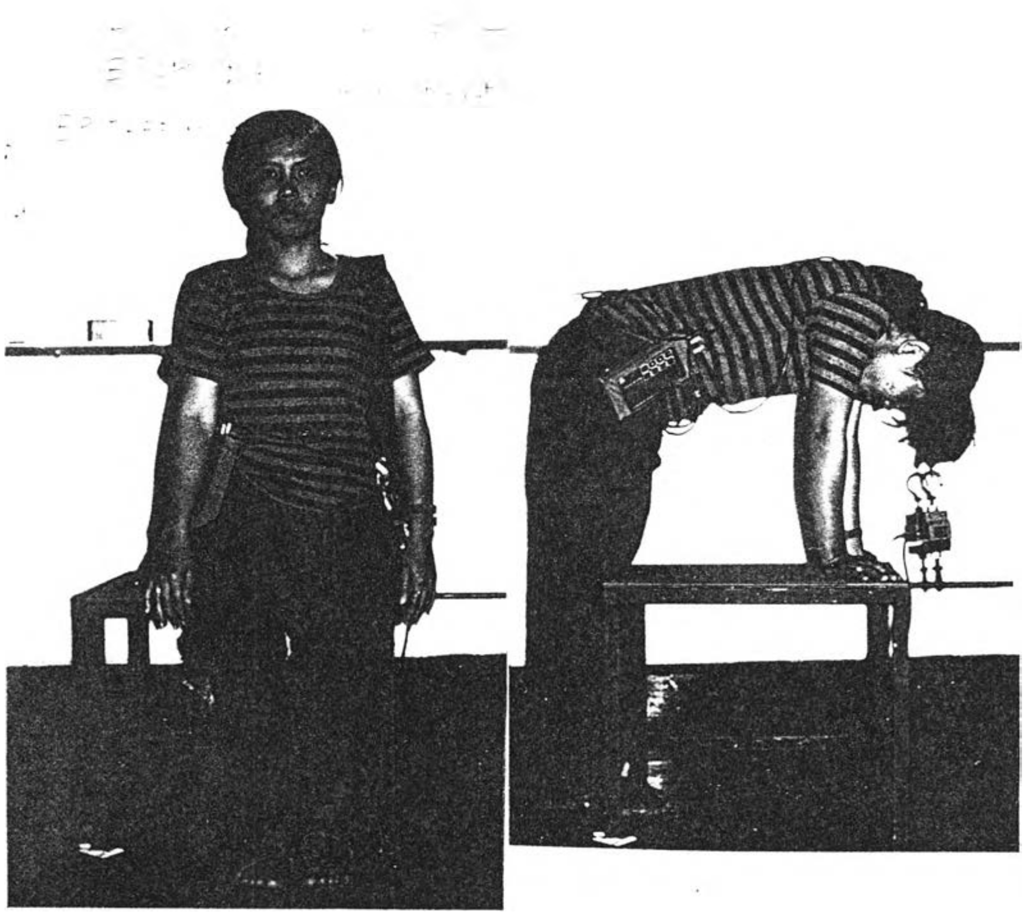
1.3.1 Measurement Method

As the working posture of the inspector was in the slight forward-bent-sitting position, the upper trapezius (for neck and shoulder muscle) and lower trapezius (for back muscle) were measured. Two surface electrodes were attached to the surface of the skin above the individual muscle. The attach positions were found by using on electronic pulse massager. The electrical signal of the muscles was recorded in the memory of the collecting device at a time constant of 10.0 seconds. The data could be unpacked onto the tester's display and transferred via optical terminal to computer for analyzing.

Before testing, EMG data of full rest situation of each subject was needed to compare with the working situation.

1.3.2 EMG Calibration

The reference voluntary force (RVC) was assessed for neck and shoulder muscles. The RVC of the left shoulder was measured with a strip over the acromion in a sitting position using a strain gauge dynamometer (Figure 3.2a). The RVC of the neck muscle was obtained by a strip around the head connected to a strain gauge dynamometer (Figure 3.2b). The best of three RVC was considered to be the subject's reference isometric strength.



(a) upper trapezius (b) neck

Figure 3.2 Method for measurement of reference contraction force.

1.4 <u>Heart Rate</u>

In order to assess the general fatigue, sport tester was used to record the heart rate during work. The measurement was done at the same time as EMG measurement.

1.4.1 Measurement Method

The subject was equipped with a sport tester for heart rate recording. The signal of heart rate was recorded in the solid state memory of the collecting device (watch) at a time constant of 15 seconds.

During recording of EMG and heart rate, the activities of the subject were recorded by manual in an activity form throughout the working time. This was necessary to analyze both data.

2. Methods of Analysis

Fuzzy set theory is employed as a mathematical tool to indicate the effect and strength of contributing factors to mental fatigue. The basic problem can be formulated as follows : Let $X = \{x_1, x_2, x_3, x_4\}$ constitute the set of decision alternatives corresponding to the four contributing factors, where x_1 = shift, x_2 = rest allowance, x_3 = sleeping hours on the day before testing, and x_4 = work output. The objective is to prioritize the weights associated with these factors and determine the correspondence between these weights and their representation in the multiple regression model as predictors of each measuring method, i.e. CFF(up- and down- measurement) and reaction time (light and sound stimuli). Methods of analysis (Wang, Sharit and Drury, 1986; Kitti Intaranont and Vanwonterghem, 1993) are described as follows :

1. Transforming means of each measurement to Z-value (standard normal variable).

2. Deriving a coefficient from a linear regression analysis of each factor for each measuring method.

3. Constructing a matrix A (4x4) of which elements $a_{ij} = c_i/c_j$ indicate the relative coefficient with which factor (i) dominate to factor (j). The general form of the matrix A is

$$
A = \begin{array}{c} \\ \mathbf{S} \\ \mathbf{R} \\ \mathbf{Sp} \\ \mathbf{Op} \end{array}
\begin{array}{c}
\begin{array}{cccc} \mathbf{S} & \mathbf{R} & \mathbf{Sp} & \mathbf{Op} \end{array} \\
\begin{bmatrix}
a_{11} & a_{12} & a_{13} & a_{14} \\
a_{21} & a_{22} & a_{23} & a_{24} \\
a_{31} & a_{32} & a_{33} & a_{34} \\
a_{41} & a_{42} & a_{43} & a_{44}
\end{bmatrix}
\end{array}
$$

where S = Shift
R = Rest allowance
Sp = Sleeping hours on the day before testing
Op = Work output
a_{ij} = The relative coeffecient with which factor (i) dominates to factor (j)

4. Calculating an eigenvector (w) and the largest observed eigenvalue which satisfies $Aw = L_{max}w$. This equation is the definition of a matrix operation, $Aw = nw$, where n = an eigenvalue. This study employs a MATHCAD computer package to solve for L_{max} and w.

5. Constructing a decision set, D = fatigue level, by selecting for each factor the largest membership value in any of the measuring method :

$$D = A_1 \cup A_2 \cup A_3 \cup A_4$$

A_1 = the decreasing frequency of CFF-UP
A_2 = the decreasing frequency of CFF-DOWN
A_3 = the increasing response time of LIGHT
A_4 = the increasing response time of SOUND

6. Make an optimal decision by selecting the alternative with the highest membership in D.

By normalzing the eigenvector, the appropiate values in terms of membership functions are obtained.