CHAPTER IV

# RESULTS AND DISCUSSION

## Work Analysis

### 1. Organization

The operating time is 24 hours a day so three shift works have to be carried out. The rotation of shift is every two weeks from morning to night, night to afternoon and afternoon to morning. The working week comprises of six working days from Monday through Saturday, and follows by a free Sunday. Work schedule of each shift is as follows :

06:30 a.m. - 03:00 p.m. (morning)
02:30 p.m. - 11:00 p.m. (afternoon)
10:30 p.m. - 07:00 a.m. (night)

There are two meal breaks in each shift. The first break, 30 minutes, is after working 1.5 hours and the other, 40 minutes, is after 4 and a half hours of work. Furthermore, the operators in inspection process are allowed to get a 5-minute-break after an hour working .

### 2. Task Description

Electronic chips are filled in an embossed carrier with a top cover (Figure 4.1). One reel of the carrier comprises of three thousand chips.

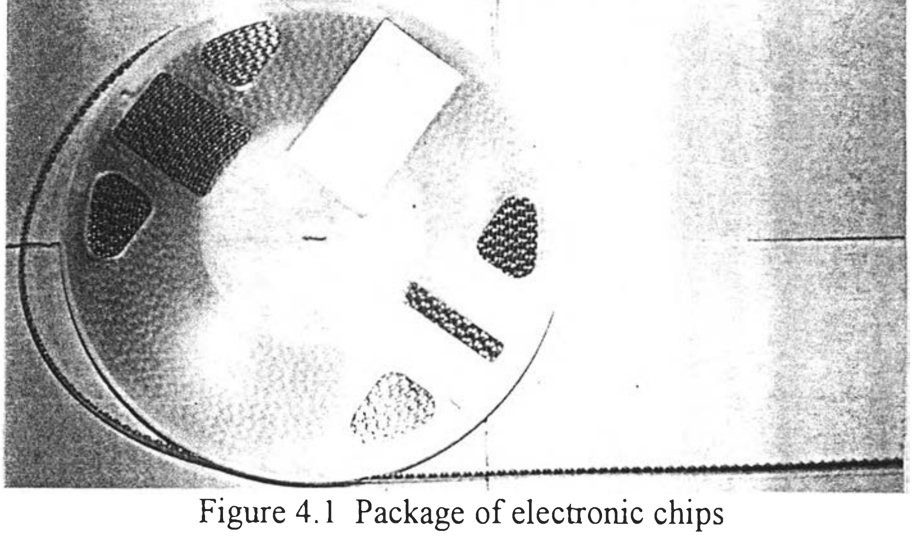


Figure 4.1 Package of electronic chips

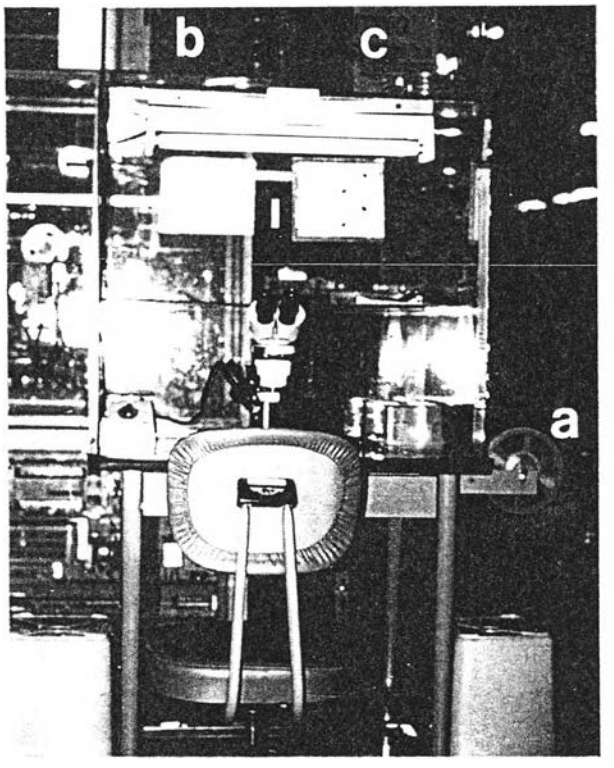



Figure 4.2 Work Station of inspection process

The inspection task could be described in sequence as follows :

1. Get a lot of carriers (about 3 - 20 reels) from a storage shelf and carry it for a distance of 2 metres.
2. Record details of products using a lot control sheet.
3. Set the carrier reel to a spindle on (a).
4. Orient the item to be inspected by pulling the carrier tape with left hand.
5. Visual inspect the product by using a microscope.
6. Detect a flaw or unusual phenomenon.
7. Recognize and classify the phenomenon.
8. Decide on a status of an item.
9. If the item is a defect, change a perfect one instead.
10. Record information pertaining to the item.
11. Repeat step 4 to 10 until it finished.
12. Take the finished reel to (b).
13. Take the new reel from (c).
14. Repeat 3 - 13 until the lot is finished.
15. Record the total defects.
16. Collect the finished lot to packing station which is 3 meters distance.

3. <u>Environmental Condition</u>

3. Environmental Condition

For a reason of the product's characteristics, the temperature and the humidity are controlled to be 25 ± 3 °c and 50 ±10 %RH, respectively. Noise level and light intensity were measured by laboratory's equipment, and temperature and humidity were measured by Thermohygrographic equipment. The environment is summarized in table 4.1.

Table 4.1 Environmental Conditions

| Type of Environment | Environmental Conditions |
|---|---|
| Noise Level [dB(A)] | 79 ± 2 |
| Light Intensity (Lux) | 15180 ± 80 |
| Temperature ( °c) | 25.5 ± 1.5 |
| Humidity (% RH) | 51.5 ± 6.5 |

4. Work Output

The quantity of work output was recorded by the number of reels that were inspected. Table 4.2 shows the output inspected in morning shift and night shift.

Table 4.2 Quantity of Work output

| Shift | Work output (reels) |
|---|---|
| Morning | 33.22 |
| Night | 27.00 |

The target of work output that is set by management objectives is 18 reels per shift, hence the variation of the output was acceptable. This variation might cause by attitudes to work, social factors and health. The accident has never occurred in this process, so it is not the cause of the output variation.

## Experimental Results

### 1. Results of CERGO Questionnaire

There were two types of the questionnaire used in this test. One concerned with worker's health and the other one concerned with job. The questionnaires were asked to 12 operators whose age, height and weight were 21.5 ± 2.5 years (mean = 21.25 years), 156.5 ± 8.5 centimetres (mean = 153.58 cm.), and 50 ± 10 kilograms (mean = 45.92 kg.).

In the first questionnaire, all the inspectors claimed about the pain, some happened after work and some during work. Almost the pain occurred at their necks and shoulders. Some operators got pain at their upper and lower backs. However, the pain disappeared in the next day. The cause of the pain might be caused by the inappropiate sitting posture or work bench itself.

The other questionnaire concerned about job content, job interest and fatigue. The scales are calculated into abnormal index (AI) as shown in appendix B.2. The calculated AI of the operators (Appendix E.1) are in the range of -0.75 to 1.75 which means that there is no particular problem. Even though they feel that their jobs are difficult and need high responsibilities, their attitudes on it are quite well, i.e. that the job itself is interesting and they can make decisions independently.

### 2. Analysis of Training Effects on Measuring Apparatus

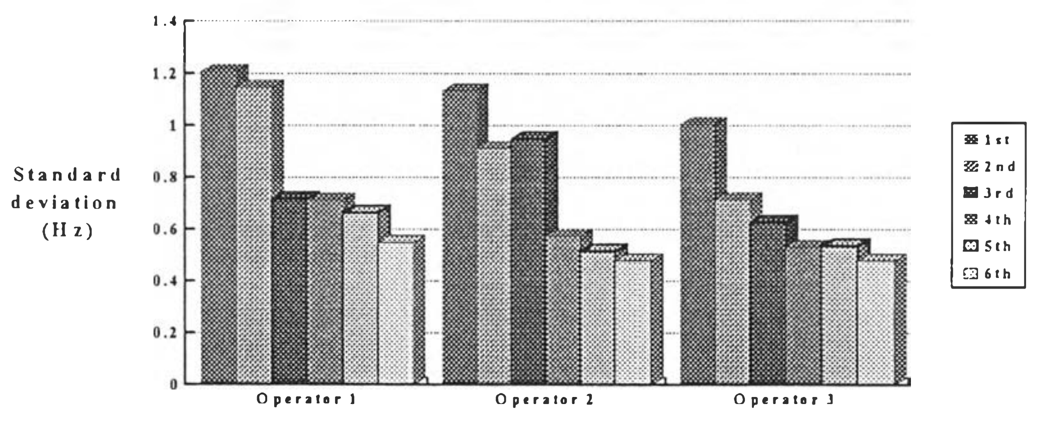
In order to decrease the effect of learning that might influence to the data, the training for using the equipment were introduced in three days (6 times) before starting the experiment. Critical Fusion Frequency (CFF)equipment was measured 5 times for each measurement while reaction time equipment was measured 10 times. The results are shown in Appendix E.2.

The effect of training could be shown in term of ' Standard Deviation (STD) ' decreased after training times. This effect is presented in Table 4.3 and Figure 4.3 for training on CFF apparatus, and Table 4.4 and Figure 4.4 show training on reaction time apparatus. They indicate that STD are high at the beginning of training and become less and less. This is accepted that the measured data from both equipment are reliable.

Table 4.3 Standard deviation of flicker values on each training

| Type of measurement | Subject | STD of flicker values for each measurement | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Up-measurement | 1 | 1.207 | 1.146 | 0.715 | 0.712 | 0.662 | 0.548 |
| | 2 | 1.135 | 0.913 | 0.948 | 0.574 | 0.515 | 0.479 |
| | 3 | 1.007 | 0.714 | 0.625 | 0.532 | 0.534 | 0.479 |
| Down-measurement | 1 | 1.020 | 1.328 | 1.250 | 1.089 | 0.754 | 0.769 |
| | 2 | 1.289 | 1.109 | 0.829 | 0.637 | 0.591 | 0.512 |
| | 3 | 0.614 | 0.601 | 0.574 | 0.506 | 0.506 | 0.468 |

Up-measurement




Down-measurement

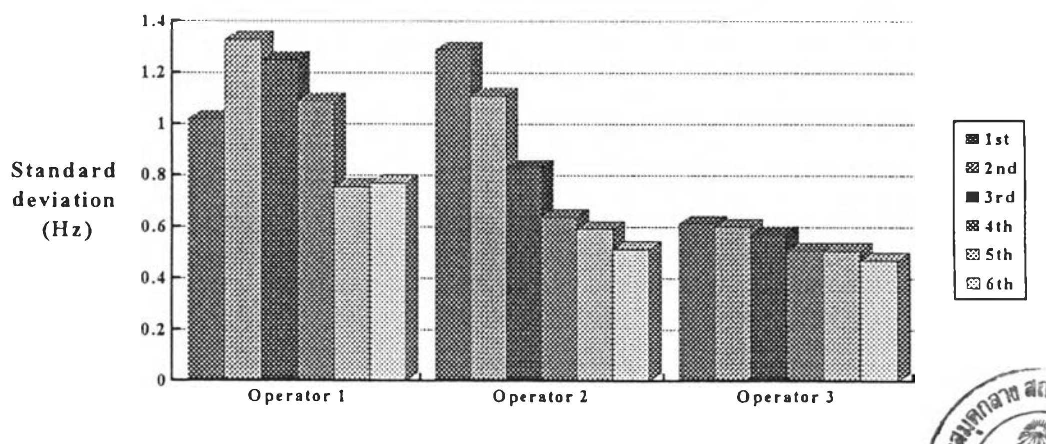
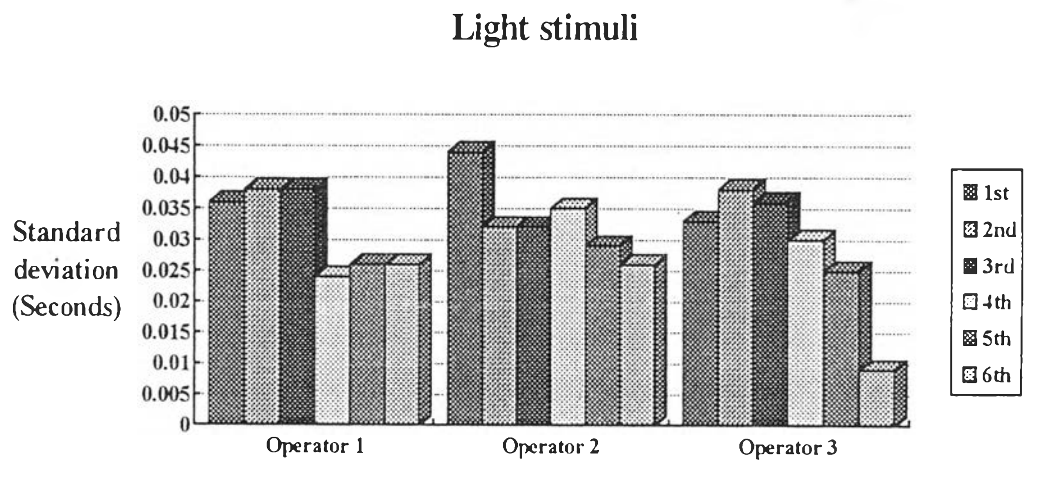



Figure 4.3 Standard deviation decrease of flicker values.

Table 4.4 Standard deviation of reaction time on each training

| Type of measurement | Subject | STD of reaction time on each training | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| Light response | 1 | 0.036 | 0.038 | 0.038 | 0.024 | 0.026 | 0.026 |
| | 2 | 0.044 | 0.032 | 0.032 | 0.035 | 0.029 | 0.026 |
| | 3 | 0.033 | 0.038 | 0.036 | 0.030 | 0.025 | 0.009 |
| Sound response | 1 | 0.030 | 0.033 | 0.022 | 0.022 | 0.017 | 0.016 |
| | 2 | 0.027 | 0.016 | 0.016 | 0.016 | 0.010 | 0.006 |
| | 3 | 0.030 | 0.025 | 0.027 | 0.022 | 0.014 | 0.015 |



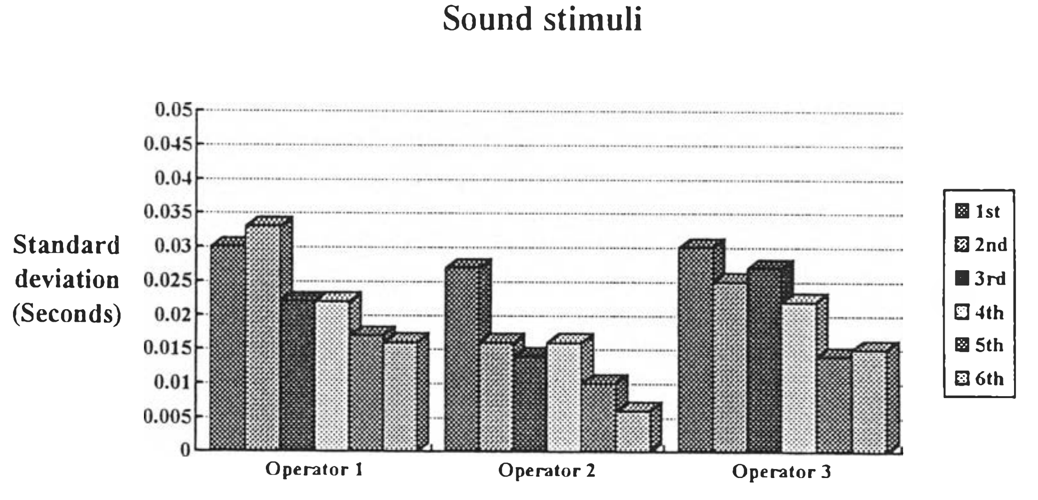




Figure 4.4 Standard deviation decrease of reaction time.

3. Analysis of Experimental Results

Prior to analyze the collected data (Appendix E.3), the hypothesis of fatigue appearance of each equipment is needed to be tested, otherwise later analysis could not be continued.

3.1 Test of Fatigue Appearance Hypothesis.

The flicker values of CFF on after-work should be less than those on before-work, both up-measurement and down-measurement of CFF. Opposite to the mention above, reaction times will increase as a sign of mental stress.

Statistical test was done for the data before and after work by using a paired-sample test. The testing data shows that the difference of data between before-work and after-work are significantly different and the means of the results from both equipments are corresponding to the hypothesis (Appendix E.4). That is, the means of flicker frequency values of after-work are less than the means of those of before-work, both up-measurement and down-measurement(Figure 4.5a); the means of reaction time of before-work, both light stimuli and sound stimuli, are higher than the means of after-work (Figure 4.5b).

In conclusion, both the CFF and reaction time apparatus are able to be used to measuring the mental fatigue before-work and after-work as the hypothesis.

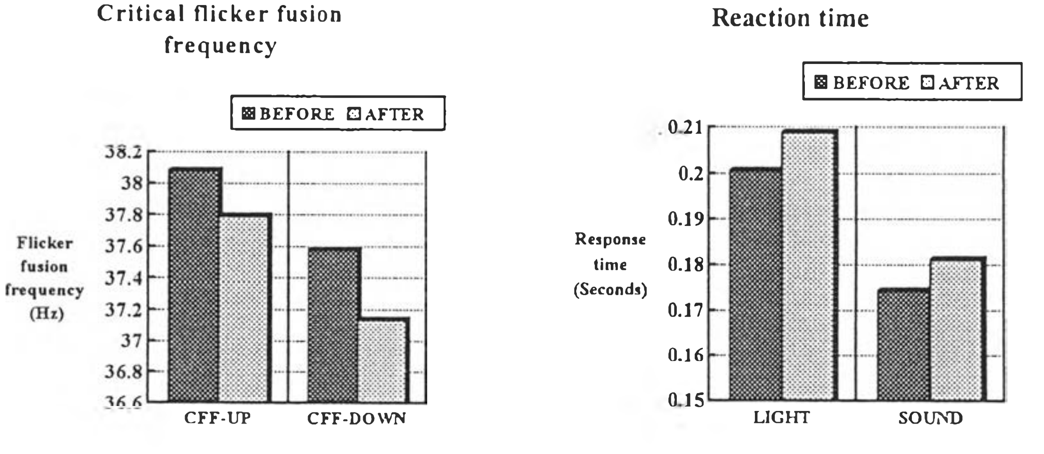



Figure 4.5 Comparison of means from measuring equipment, before and after work.

3.2 Test of Relationship between Objective and Subjective Methods of Fatigue measurement

To see whether the self-scaling questionnaire is suitable, the scale of each opposing predicate was compared to the fatigue level from CFF and reaction time.

Table 4.5 indicates R-square of each opposing predicate that has not any relationship to the fatigue level from those equipment. This means that the results from self-scaling questionnaire are not suitable to use for assessing mental fatigue on the inspection task. It can be explained that it is difficult for the operators to scale this kind of questionnaire or the operators may believe that they could get more rest or other compensation owing to over scaling the questionnaire.

Table 4.5 Relationship between objective and subjective methods of fatigue measurement.

| Principle of opposing predicates | R - square | | | |
|---|---|---|---|---|
| | CFF-UP | CFF-DOWN | LIGHT | SOUND |
| Interested - bored | 0.0229 | 0.1344 | 0.0297 | 0.0610 |
| Ready for action - dull | 0.0738 | 0.0408 | 0.0375 | 0.0035 |
| Refreshed - tired | 0.0060 | 0.0620 | 0.0049 | 0.0077 |
| Strong - weak | 0.0321 | 0.0250 | 0.0127 | 0.0527 |
| Vigorous - exhausted | 0.0385 | 0.0027 | 0.0349 | 0.0562 |
| Awake - sleepy | 0.0203 | 0.0697 | 0.0028 | 0.0350 |
| Relaxed - tense | 0.0000 | 0.0695 | 0.0527 | 0.0001 |

**Note :** Dependent variable = principle of opposing predicates
Independent variable =
CFF-UP (the flickering light appeared into a constant shining light),
CFF-DOWN (the constant shining light become flickering),
LIGHT (reaction time for light stimulus),
SOUND (reaction time for sound stimulus).

### 3.3 Comparison of Fatigue between Shifts

To understand whether night or morning shift causes higher fatigue, the fatigue level from each measuring method was compared. The fatigue level is determined by the decreasing frequency of CFF and the increasing response time of reaction time after work. It can be easily seen in Figure 4.6 that the decreasing frequency of CFF, both CFF-UP and CFF-DOWN, and the increasing response time, both light stimuli and sound stimuli, show the same trend. That is, the operators working in the night shift get more fatigue than working in the morning shift. Moreover, the work output in morning shift is more than the one in night shift as shown in Figure 4.6.

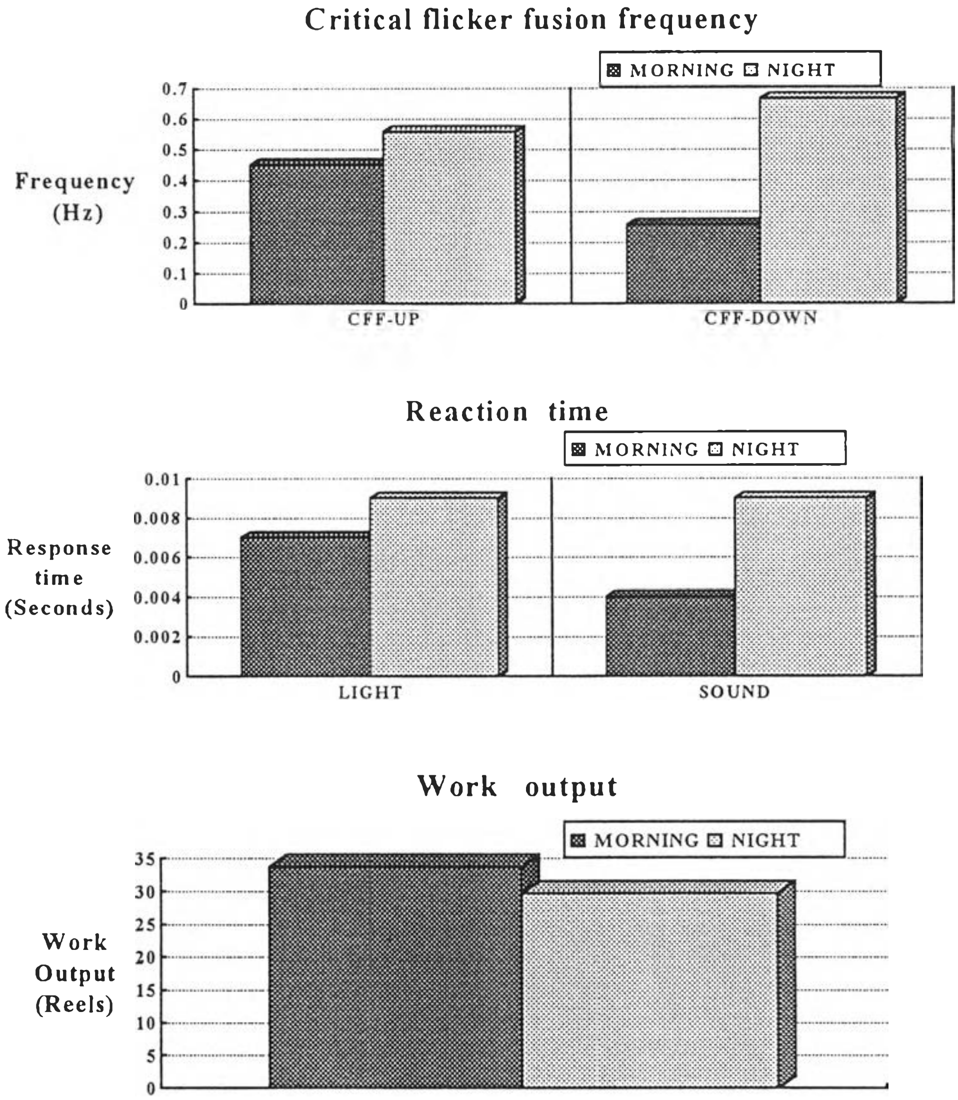
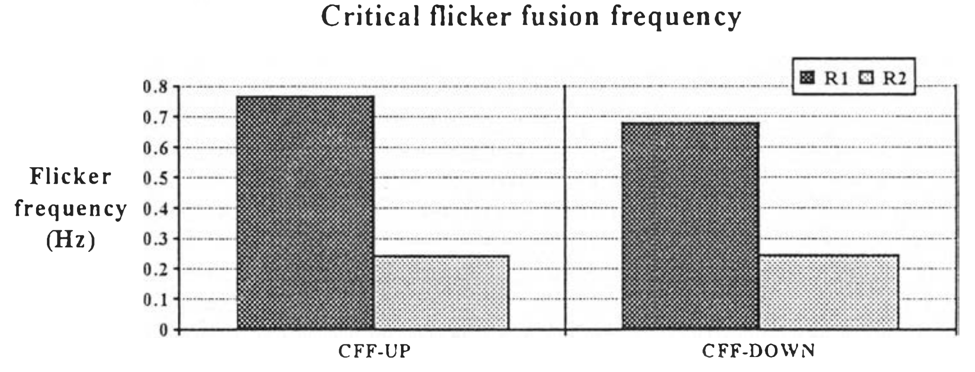
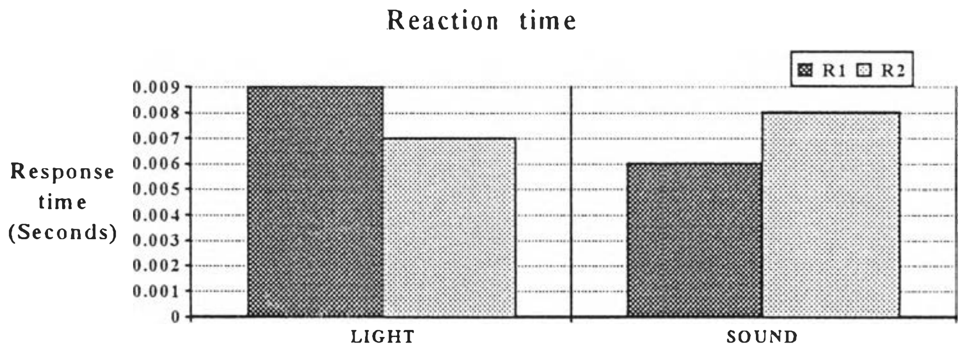



Figure 4.6 Comparison of fatigue between shifts.

3.4 Comparison of Fatigue between Rests.

By the same method as 3.3, the fatigue level from each measuring method was compared between the existing rest allowances (R1) and the rearranged rest time (R2). CFF shows that R1 has statistical significantly higher fatigue than R2 and work output of R1 is less than R2. However, no statistical significant differences are found in reaction time between R1 and R2.



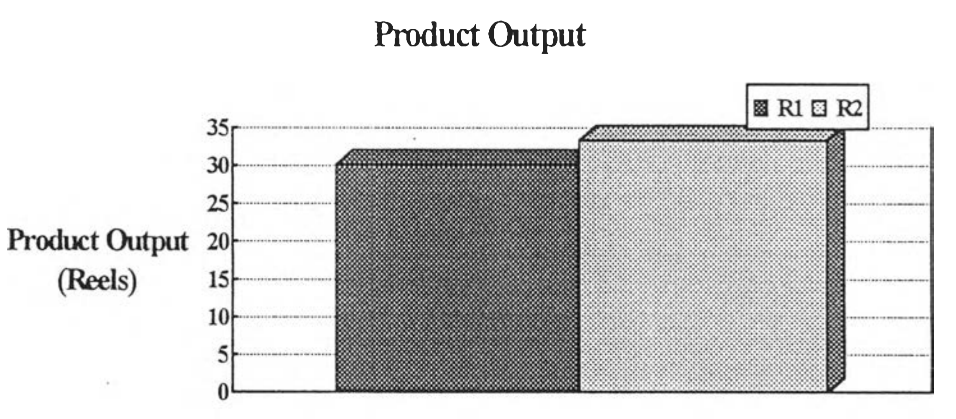




Figure 4.7 Comparison of fatigue between rests.

### 3.5 Comparison of Fatigue between Paced-Work.

The introduction of new device for pulling carrier tape was not encouraged. The reasons are explained as follows.

In order to replace the manual operation of pulling carrier tape with a mechanized system, it is necessary to train operators to be familiar with the new machine. During that time, it was found that the output quantity decreased and that the operators refused to use the pulling machine. This attitude can be explained as follows.

In a manual command system, an inspection task is based on a cooperation of rhythmic pulling hand and interval focus of eyes. The used strategy will involve to a stereotype movement of which the coordination is controlled by brain that also functions as a decision of quality. Thus, the speed of the process is a result of the coordination between 'detection' of defects (mental effort) and 'speed inducing' (physical effort) factors. Moreover, the replacement to the found defect by a new good workpiece increases the cycle time with 5% for each operation. This means that the variation in speed is, in the random detection of an unpredictable number of errors, a function of the number of corrections. Therefore, this unpredictable and unreliable process cannot be rationed by using a mechanical system for detection. Furthermore, the correction activity in the mechanical system causes a long delay because the system does not allow an easy way to repair the workpiece.

In the actual existing system, production output is always more than the target that is set by the management. This, obviously, is the reason why the operators rejected the mechanized input system in which the speed is determined by the machine. The fear to omit some of the replacements by a non personal controlled device will be the barrier of acceptance, and whether the machine speed is lower or higher, the operators do not believe in this machine's capability.

The mentioned factors cause a fundamental problem in this project where we have tried to improve the quality by replacing the manual operation of pulling the carrier by a mechanized system. However, if the number of workpieces to be checked must be increased, as the aim of management, the quantity of errors will be detected before input to the final check, or repaired in different station. The contribution of the workers was, therefore, important because it protected us for a task which could never be successful finished. If the mentioned items is modified and improved, the speed will be increased an d the process will be mechanized. The further study is worthwhile to be taken over in another project.

### 3.6 Analysis of Results by the Fuzzy Set Theory Application.

Since the experiment are concerned not only with whether the determined factors, shift and rest allowance, effect to the mental fatigue the inspection, but also with how strongly they belong to it, a fuzzy set theory approached to make decision. The strength they belong to is shown in term of a grade of membership that obtains as the methods mentioned in Chapter II.

The calculation of eigenvalue to determine the importance of contributing factors to the dependent variable by methods of measurement is summerized as follows :

Methods of measurement : CFF up-measurement

1. Dependent variable : CFF-UP

2. Indepedent variables : Shift, Rest, Sleeping hours, Work output

3. Coefficients of factors

| | |
|---|---|
| Shift (S) | 0.371390056 |
| Rest (R) | 1.079535257 |
| Sleeping hours ($S_p$) | 0.037390380 |
| Work output ($O_p$) | 0.0260791210 |

4. Matrix (4x4)

$$\begin{array}{c|cccc} & S & R & S_p & O_p \\ \hline S & 1 & 1/3 & 10 & 1 \\ R & 3 & 1 & 29 & 4 \\ S_p & 1/10 & 1/29 & 1 & 1/7 \\ O_p & 1 & 1/4 & 7 & 1 \end{array}$$

5. Eigenvector

| Eigenvalue | S | R | Sp | Op |
|---|---|---|---|---|
| 4.013 | 0.290 | 0.924 | 0.032 | 0.247 |

Methods of measurement : CFF down-measurement

1. Dependent variable : CFF-DOWN

2. Indepedent variables : Shift, Rest, Sleeping hours, Work output

3. Coefficients of factors

| | |
|---|---|
| Shift (S) | 0.8216577321 |
| Rest (R) | 0.8779130228 |
| Sleeping hours ($S_p$) | 0.0822263919 |
| Work output ($O_p$) | 0.1738170169 |

4. Matrix (4x4)

$$\begin{array}{c c} & \begin{array}{cccc} \mathbf{S} & \mathbf{R} & \mathbf{S_P} & \mathbf{O_P} \end{array} \\ \begin{array}{c} \mathbf{S} \\ \mathbf{R} \\ \mathbf{S_P} \\ \mathbf{O_P} \end{array} & \begin{bmatrix} 1 & 1 & 10 & 5 \\ 1 & 1 & 10 & 5 \\ 1/10 & 1/10 & 1 & 1/2 \\ 1/5 & 1/5 & 2 & 1 \end{bmatrix} \end{array}$$

5. Eigenvector

| Eigenvalue | S | R | Sp | Op |
|---|---|---|---|---|
| 4.001 | 0.690 | 0.707 | 0.067 | 0.138 |

Methods of measurement : Reaction time - light stimulus

1. Dependent variable : LIGHT

2. Indepedent variables : Shift, Rest, Sleeping hours, Work output

3. Coefficients of factors

| | |
|---|---|
| Shift (S) | 0.1849017364 |
| Rest (R) | 0.1959196341 |
| Sleeping hours ($S_p$) | 0.0784138808 |
| Work output ($O_p$) | 0.1433660952 |

4. Matrix (4x4)

$$
\begin{array}{c|cccc|}
 & \mathbf{S} & \mathbf{R} & \mathbf{S_P} & \mathbf{O_P} \\
\hline
\mathbf{S} & 1 & 1 & 2 & 1 \\
\mathbf{R} & 1 & 1 & 3 & 1 \\
\mathbf{S_P} & 1/2 & 1/3 & 1 & 2 \\
\mathbf{O_P} & 1 & 1 & 2 & 1 \\
\end{array}
$$

5. Eigenvector

| Eigenvalue | S | R | Sp | Op |
|---|---|---|---|---|
| 4.718 | 0.503 | 0.585 | 0.390 | 0.503 |

Methods of measurement : Reaction time - sound stimulus

1. Dependent variable : SOUND

2. Indepedent variables : Shift, Rest, Sleeping hours, Work output

3. Coefficients of factors

| | |
|---|---|
| Shift (S) | 0.933899539 |
| Rest (R) | 0.496052653 |
| Sleeping hours ($S_p$) | 0.125265365 |
| Work output ($O_p$) | 0.101380637 |

4. Matrix (4x4)

$$\begin{array}{c} \\ S \\ R \\ Sp \\ Op \end{array} \begin{array}{c} \begin{array}{cccc} S & R & Sp & Op \end{array} \\ \begin{bmatrix} 1 & 2 & 7 & 9 \\ 1/2 & 1 & 4 & 5 \\ 1/7 & 1/4 & 1 & 1 \\ 1/9 & 1/5 & 1 & 1 \end{bmatrix} \end{array}$$

5. Eigenvector

| Eigenvalue | S | R | Sp | Op |
|---|---|---|---|---|
| 4.009 | 0.873 | 0.463 | 0.113 | 0.101 |

The eigenvectors of experimental factors are concluded in Table 4.6

Table 4.6 The eigenvectors of experimental factors.

| Measuring method | Shift | Rest | Sleep | Output |
|---|---|---|---|---|
| **CFF-UP** | 0.290 | 0.924 | 0.032 | 0.247 |
| **CFF-DOWN** | 0.690 | 0.707 | 0.067 | 0.138 |
| **LIGHT** | 0.503 | 0.585 | 0.390 | 0.503 |
| **SOUND** | 0.873 | 0.463 | 0.113 | 0.101 |

The decision set, D, is found to be :

D = {0.873/Shift, 0.924/Rest, 0.390/Sleep, 0.503/Output}

Normalization of the membership for D is

D = {0.324/Shift, 0.344/Rest, 0.145/Sleep, 0.187/Output}

The priority of importance is seen to be : (1) rest allowance, (2) shift, (3) work output and (4) sleep hours on the day before testing. Figure 4.8 depicts the proportion of factors effect to the fatigue level.

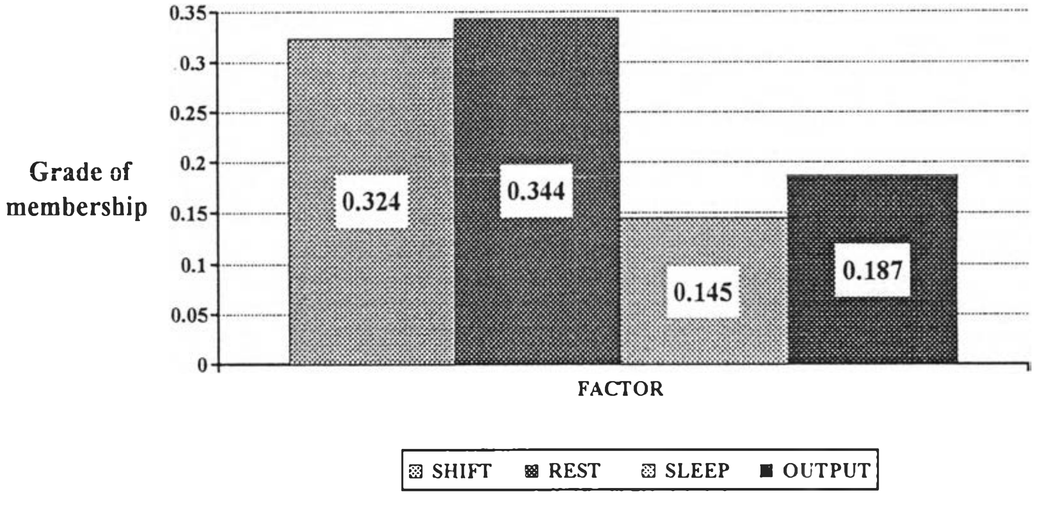
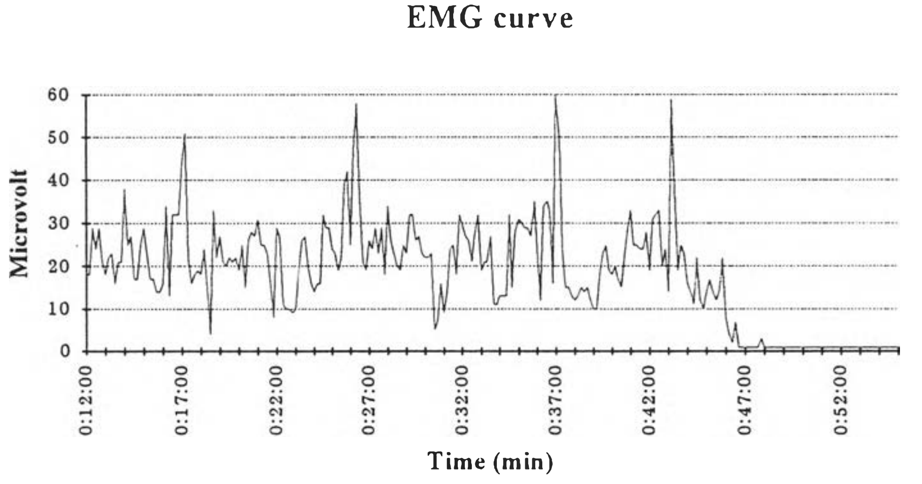



Figure 4.8 The proportion of factors effect to fatigue level.

3.7 Analysis of Electromyography and Heart Rate

Work activities that were recorded in the activity-log sheet are allocated onto the EMG and heart rate curve. The activities are grouped into four main activities; direct work (D), indirect work (I), ideal work (X) and break (B). Direct work is all the inspecting activities as described in 'task description' exept the activities of transportation (walking). Indirect work is all the working activities except direct work such as transportation (walking), meeting, documental work, etc. Ideal work is all the activities that does not concern with the work and happens during working time such as talking, drinking, personal business, etc. Break is meal break. Figure 4.9 illustrates example of the EMG and heart rate graph of inspection task performed. Mean weighted average of EMG and heart rate of each activity are calculated for each measurement.



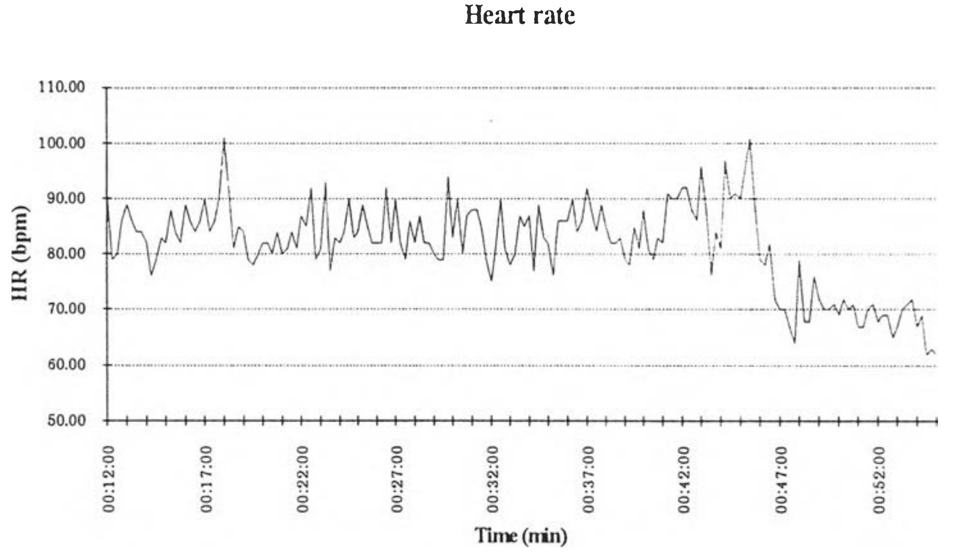




Figure 4.9 EMG and heart rate

Figure 4.10a, 4.10b, 4.10c indicates the absolute values of EMG in $\mu V$ for direct work, indirect work and EMG at rest. It can be observed that response on direct work can represent total response of workload (D+I) for all muscle groups, upper trapezius, lower trapezius and neck. Moreover, there is a sign of an evolution of fatigue which is the decreasing EMG at the end of 4-week period (the last day of the 4$^{th}$ week, E4). This subject will be discussed later in this chapter.

EMG OF UPPER TRAPEZIUS

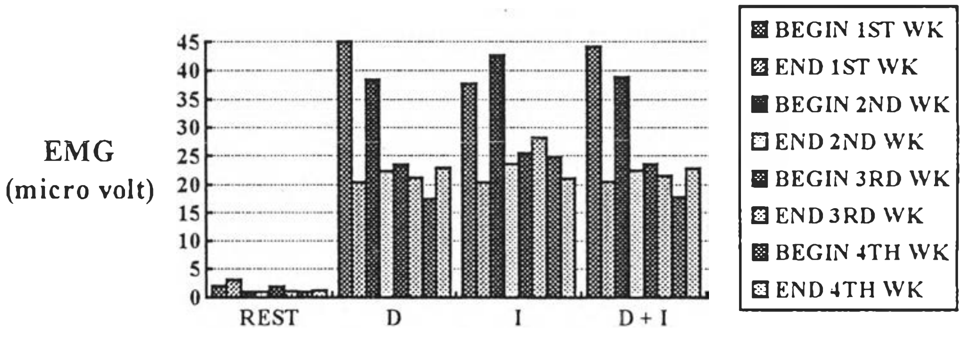



Figure 4.10a EMG of upper trapezius for direct work (D), indirect (I) and at rest.

EMG OF LOWER TRAPEZIUS

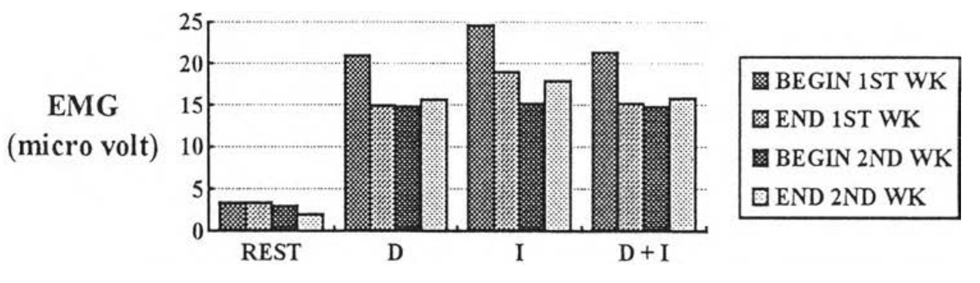



Figure 4.10b EMG of lower trapezius for direct work (D), indirect work (I) and at rest.

EMG OF NECK MUSCLE

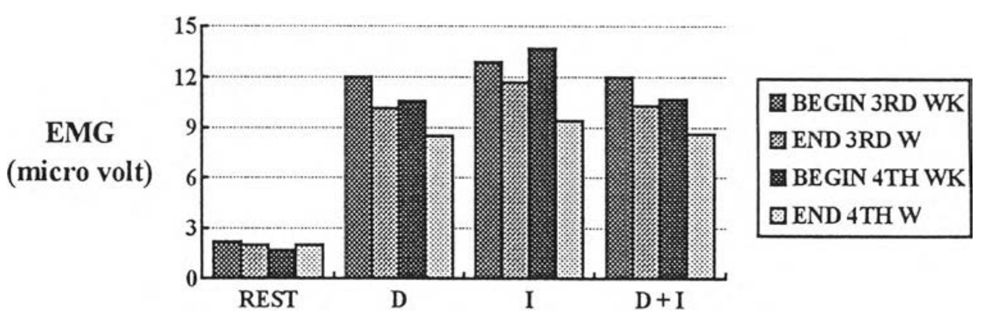



Figure 4.10c EMG of neck for direct work (D), indirect work (I) and at rest.

In practice, EMG is expressed as a percentage of muscle strength of the critical muscle group or a percentage of reference voluntary contraction (% RVC). Considering the work activities, the lower trapezius does not much relate to the workload of inspection, therefore we do not analyse on this muscle group. Heart rate is also the same as EMG that is expressed in term of %WHR.

in which %WHR = 100 (HRW-HRR) / [1/3 (220 - age)]
HRW = average heart rate at work
HRR = heart rate at rest

The result is summarized in Table 4.7, Figure 4.11 and Figure 4.12 .

Table 4.7 EMG , heart rate , output and defect for the different period of direct work.

| Period | Upper-trapezius | | Neck | | HRW | % WHR | Output (pcs) | Defect (pcs) |
|---|---|---|---|---|---|---|---|---|
| | Avg. EMG | % RVC | Avg. EMG | % RVC | | | | |
| B1 | 43.00 | 23.76 | - | - | 79.19 | 18.06 | 99,000 | 228 |
| E1 | 17.40 | 9.61 | - | - | 77.26 | 19.99 | 45,000 | 124 |
| B2 | 37.40 | 20.66 | - | - | 78.71 | 23.74 | 105,000 | 176 |
| E2 | 21.30 | 11.77 | - | - | 76.03 | 16.24 | 111,000 | 94 |
| B3 | 21.50 | 11.88 | 9.8 | 10.54 | 93.55 | 21.90 | 81,000 | 226 |
| E3 | 20.10 | 11.10 | 8.2 | 8.82 | 100.95 | 31.47 | 81,000 | 149 |
| B4 | 16.50 | 9.12 | 8.9 | 9.57 | 88.51 | 23.66 | 87,000 | 238 |
| E4 | 21.70 | 11.99 | 6.5 | 6.99 | 79.79 | 21.52 | 60,000 | 283 |

Note : In period B1 - E2, the neck muscle was not measured because the equipment was used for lower trapezius.

**Comparison of measuring value**

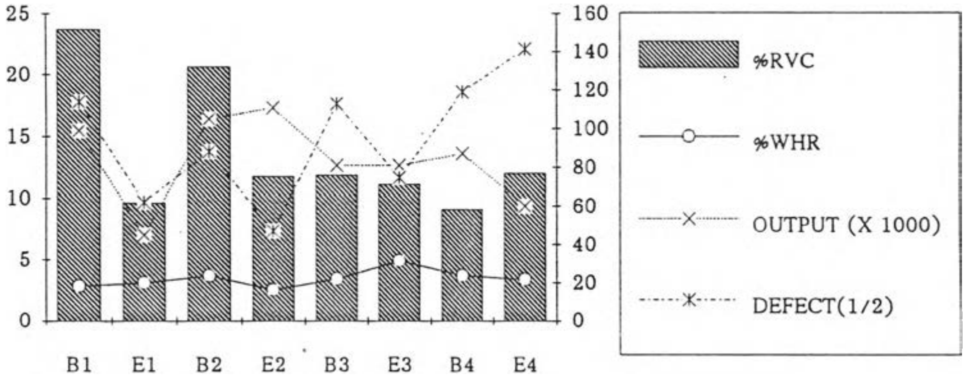



Figure 4.11 EMG of upper trapezius on direct work versus heart rate at work, output and defect (1/2)

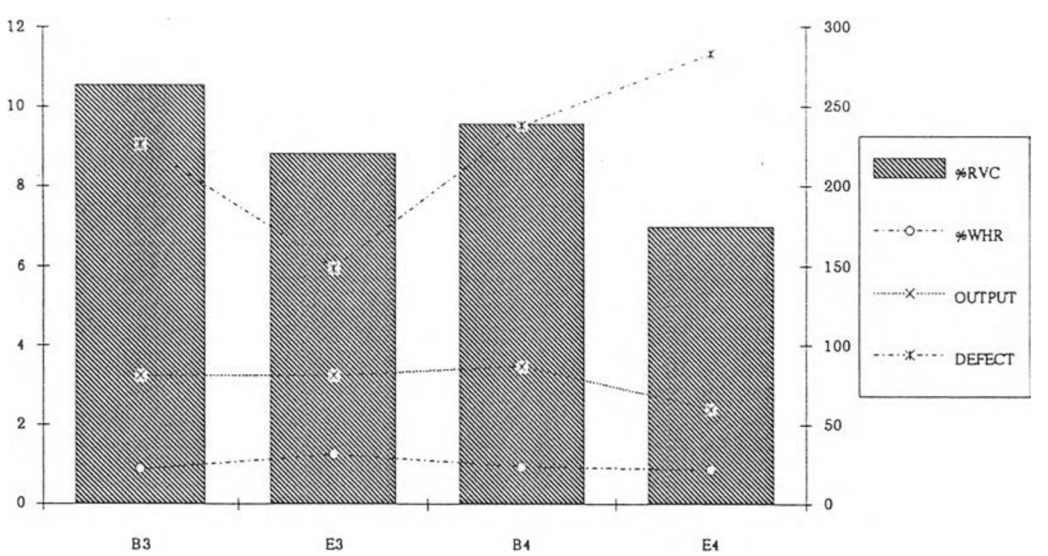



Figure 4.12 EMG of neck on direct work versus heart rate at work,output and defect (1/2)

In the last 3 periods (E3, B4 and E4) the subject caught flu and had some drugs that may affect the heart rate, therefore the data on those periods are not considered. For this reason, the relation between heart rate and EMG of neck is not considered.

There is a slight relationship between EMG and output (Table 4.8a and b). It may be expected that EMG values depend on workload which is directly determined by the quantity and quality of the input. If there are no corrections to make, workload should be low and, on the contrary, if many pieces must be replaced, workload will be higher over longer periods.

Table 4.8a Relationship among heart rate, D-EMG of upper trapezius, output and defect numbers

| | % RVC | | Output | | Defect number | |
|---|---|---|---|---|---|---|
| | $R^2$ | p | $R^2$ | p | $R^2$ | p |
| %WHR | 0.0205 | 0.8182 | 0.0322 | 0.7728 | 0.1805 | 0.4759 |
| %RVC | - | - | 0.2758 | 0.1813 | 0.0271 | 0.6967 |
| Output | - | - | - | - | 0.0322 | 0.6709 |

Table 4.8b Relationship of heart rate, D-EMG of neck,output and defect number.

| | Output | | Defect number | |
|---|---|---|---|---|
| | $R^2$ | p | $R^2$ | p |
| %RVC | 0.7216 | 0.1505 | 0.1404 | 0.0253 |

Heart rate does not relate with EMG on direct work (D-EMG), output and defect numbers. In this case, there might be other heart rate influencing parameters such as climate, noise, etc. This could be confirmed by the result in Table 4.9, though there are slightly relation between D-EMG and heart beat on indirect work per inspected unit (HBI/PC), and that between D-EMG and heart beat on ideal work per inspected unit (HBX/PC). This effect shows the basic muscle load takes place on the indirect and ideal work.

The results in Table 4.8a, 4.8b and 4.9 are obviously low correlation and not statistically significant. This is due to the fact that only one subject was tested, because of technical and organizational problems.

Table 4.9 Relationship of D-EMG and heart beat per defect number

| D-EMG | B1 to B3 | | B1 to B2 | | B2 to B3 | |
|---|---|---|---|---|---|---|
| | $R^2$ | p | $R^2$ | p | $R^2$ | p |
| HBI/PC | 0.3346 | 0.3069 | 0.2223 | 0.6874 | 0.0001 | 0.9931 |
| HBX/PC | 0.2110 | 0.4364 | 0.2673 | 0.6541 | 0.0001 | 0.9931 |
| HBIX/PC | 0.0118 | 0.8620 | 0.4482 | 0.5330 | 0.0001 | 0.9931 |
| HBI/DEF | 0.0043 | 0.9167 | 0.9515 | 0.1414 | 0.0421 | 0.8684 |
| HBX/DEF | 0.0903 | 0.6233 | 0.0033 | 0.9637 | 0.0335 | 0.8829 |
| HBIX/DEF | 0.0189 | 0.8253 | 0.2271 | 0.6830 | 0.0381 | 0.8749 |

Figure 4.13 shows the relation of D-EMG, HBI/PC, HBX/PC and HBIX/PC (heart beat on indirect and ideal work per inspected unit) while Figure 4.14 shows the relation of D-EMG, HBI/DEF (HBI per defect number), HBIX/DEF (HBIX per defect number). It is obvious that heart beat per defect number varies with D-EMG in the starting period (B1, E1, B2). On the other hand the relation in the ending period (B2, E2, B3) is different (Table 4.9). This event might be explained that there is cumulative effect of fatigue through the working period.

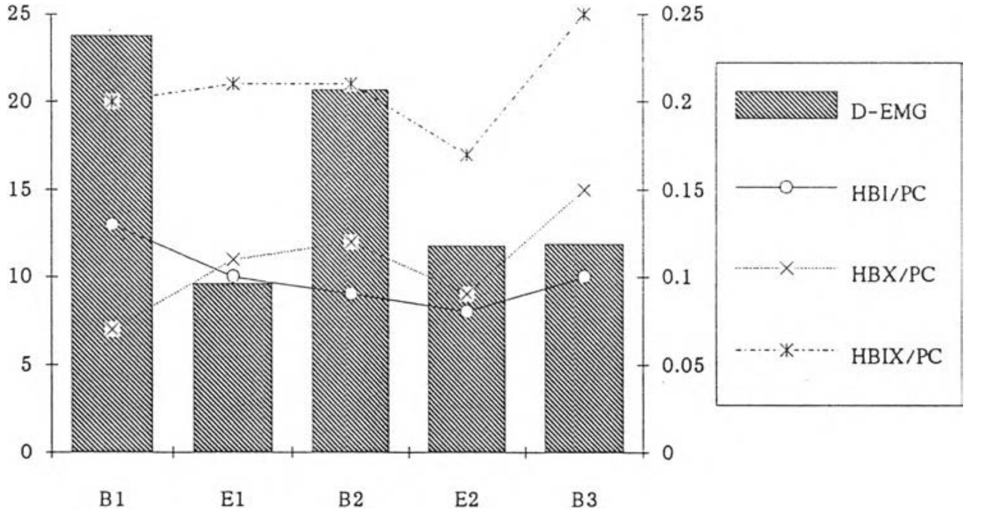



Figure 4.13 Relationship of D-EMG and heart rate per inspected unit

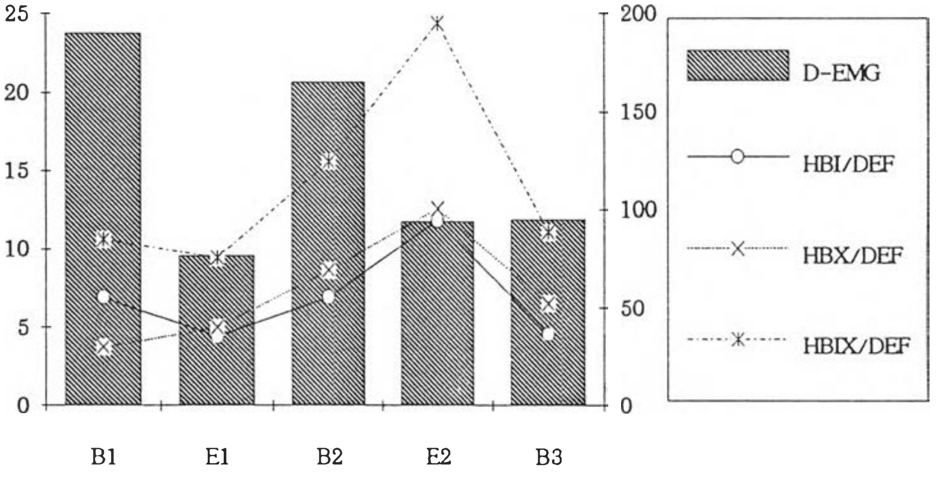
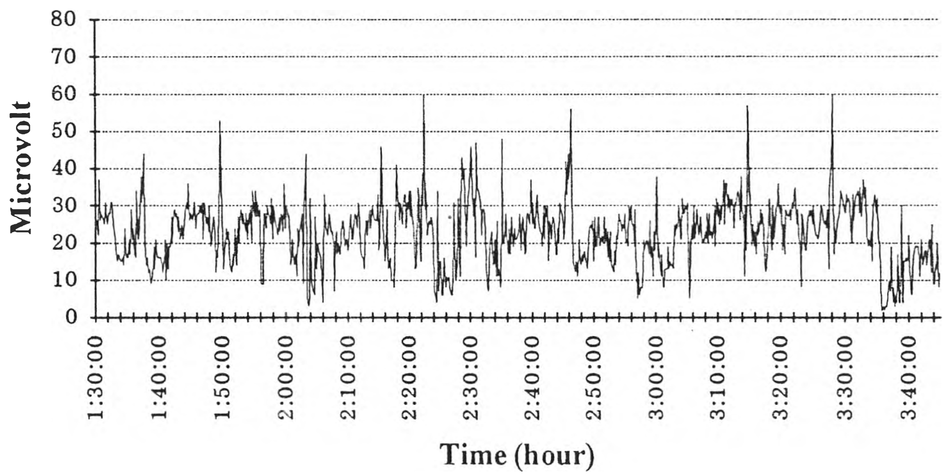



Figure 4.14 Relation of D-EMG and heart rate per defect number

As shown in Figure 4.15, EMG curve of upper trapezius behaves as being attributed by both static and dynamic load and that of neck behaves as being attributed by static load. According to Asmussen, (1973, quoted in Åstrand and Rodahl, 1986) the exercises including static and dynamic part might be performed for long period of time only if the strength does not exceed 10 to 20 percent of MVC, and the studies of Rohmert (1968, quoted in Åstrand and Rodahl, 1986) suggested that the muscle contraction might be maintained almost indefinitely as long as the endurance limit for muscular force in a continuous static contraction does not exceed 15 percent of MVC. The data of EMG, upper trapezius and neck, are classified by %RVC following the above studies and shown in Table 4.10 and 4.11

### EMG of upper trapezius




### EMG of neck

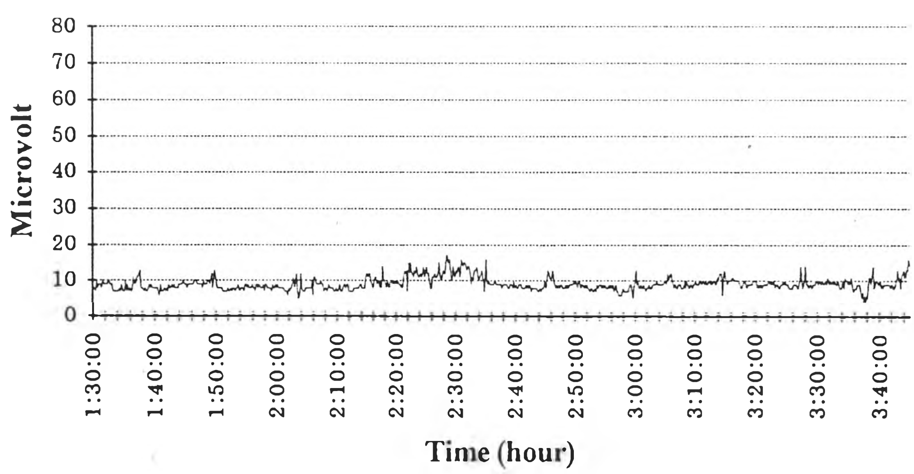



Figure 4.15 EMG curve of upper trapezius and neck.

Table 4.10 The percentage of EMG in each %RVC range of upper trapezius.

| %RVC | B1 | E1 | B2 | E2 | B3 | E3 | B4 | E4 | (%) |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 16.6 (5.07) | 49.4 (15.10) | 28.1 (8.59) | 47.2 (14.42) | 35.6 (10.89) | 47.4 (14.49) | 59.5 (18.18) | 43.4 (13.26) | (100) |
| 20 | 24.7 (7.37) | 48.2 (14.39) | 28.6 (8.54) | 41.7 (12.45) | 56.5 (16.87) | 45.6 (13.61) | 38.1 (11.37) | 51.6 (15.40) | (100) |
| >20% | 58.7 (42.60) | 2.4 (1.74) | 43.3 (31.42) | 11.1 (8.06) | 7.9 (5.73) | 7.0 (5.08) | 2.4 (1.74) | 5.0 (3.63) | (100) |

NOTE : The value in parenthesis is accumulated by row into 100%

Table 4.11 The percentage of EMG in each %RVC range of neck.

| %RVC | B3 | E3 | B4 | E4 | (%) |
|---|---|---|---|---|---|
| 12% | 35.6 (10.89) | 47.4 (14.49) | 59.5 (18.18) | 43.4 (13.26) | (100) |
| 15% | 56.5 (16.87) | 45.6 (13.61) | 38.1 (11.37) | 51.6 (15.40) | (100) |
| >15% | 7.9 (5.73) | 7.0 (5.08) | 2.4 (1.74) | 5.0 (3.63) | (100) |

For upper trapezius, the percentage of EMG data that below 20%RVC at the beginning of first week is low and increases to a certain number at the end of the week. After a rest on holiday, the percentage decreases but higher than the beginning of the week before. Then it increases to nearly the same certain number at the end of the week. This phenomenon happens repeatedly. Obviously the percentage at the beginning of each week is slightly upward as a characteristic of a muscular fatigue and full recovery after holiday dose not occur (Figure 4.16). The certain number of percentage at the end of each week might be explained as the threshold limit of workload. The percentage of EMG data above 20 %RVC shows the high percentage at the beginning of first week and decreases to the low percentage at the end. This effect can be described that the upper trapezius had less muscle capacity at the end of 4th week than the beginning.

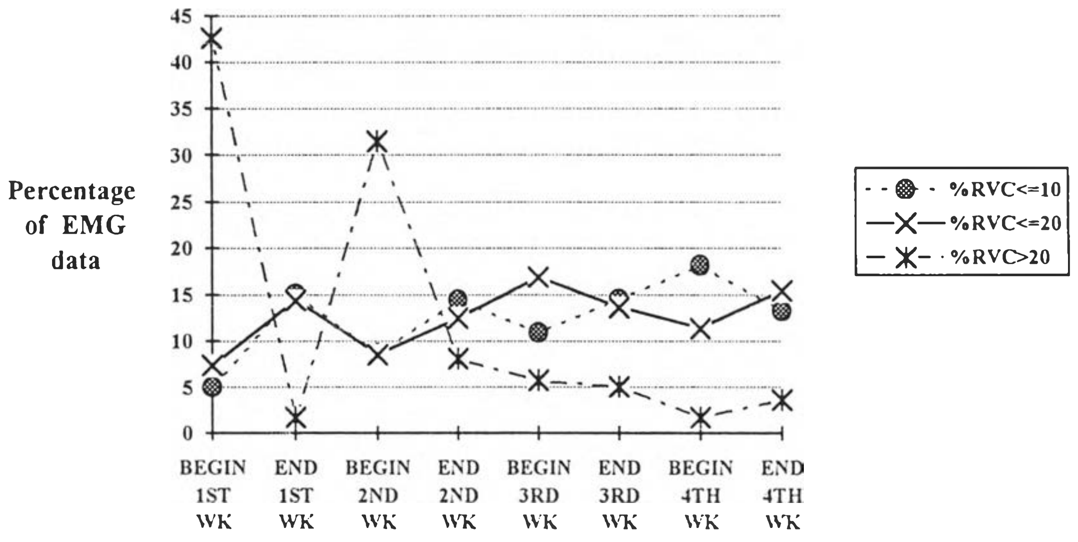



Figure 4.16 The percentage of EMG in each %RVC range of upper trapezius

The neck muscle shows the different trend at the range of 12 %RVC. The percentage of EMG data at the beginning of first measurement (3th week ) increases to a high number at the end of week. With a little recovery, the percentage slightly decreases and then increases at the end of the week. The result at the beginning and at the end of each week are both slightly upward as a sign of muscular fatigue (Figure 4.17). As the same as upper trapezius, the percentage of data above 12% RVC shows the less muscle capacity as the diminution of the percentage from the first measurement to the last.

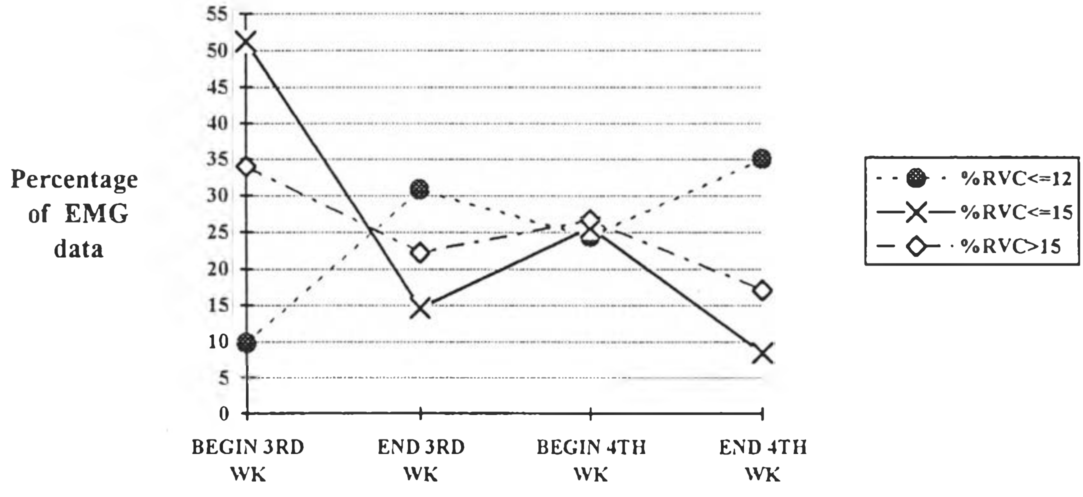



Figure 4.17 The percentage of EMG in each %RVC range of neck.

Considering the percentage of EMG data at the beginning of each week, those values of EMG which are more than 20 %RVC for upper trapezius and 15 %RVC for neck trend to decrease. The phenomenon shows an evolution of cumulative muscular fatigue and less muscle capacity. This , in long term, may constitute a risk of musculoskeletal symptoms from neck and shoulder.