IENG 301

FUNDAMENTALS OF

WORK STUDY AND ERGONOMICS

MEASURING WORK BY PHYSIOLOGICAL METHODS

- Physiologists demonstrates the validity of using rate of oxygen consumption as the basis for measuring energy expenditure.
- Studies showed that change in heart rate was also a reliable measure of physical activity.
- Physical work results in changes in;
    - Oxygen consumption,
    - Heart rate,
    - Pulmonary ventilation,
    - Body temperature, and
    - Lactic acid concentration in the blood.
- Although some of these factors are only slightly affected by muscular activity, there is a linear correlation between Heart rate& Oxygen Consumption & total ventilation& the physical work performed by and individual.
- Of these three, the first two the Heart rate & Oxygen consumption are the most widely used for measuring the physiological cost of human work.
- The performance of physical work requires the use of groups of muscles. Some muscles are needed to maintain the body posture while others perform the task
- The physical effort tasks have been classified into three types;

1) Full body work which utilizes the large muscle groups usually involving 2/3 or 3/4 of the body's total muscles,
2) Localized muscular work which requires less expenditure of energy because fewer muscle groups are used to perform the task, and
3) Static muscular work during which the muscles are used to exert a force but no mechanical work is done.

- Static work requires the contraction of muscle groups and can be very demanding.
- The physiological cost of performing a task, then, is affected by the number and type of muscles involved, either to move a member of the body or to control antagonist contraction.
- When a person is at rest, heart rate and the rate of oxygen consumption are at a fairly steady level.
- When the person does muscular work, that is, when changes from a "resting level" to a "working level", both the heart rate and the oxygen consumption increase.
- When work ends, recovery begins, and the heart rate and oxygen consumption return to the original level.

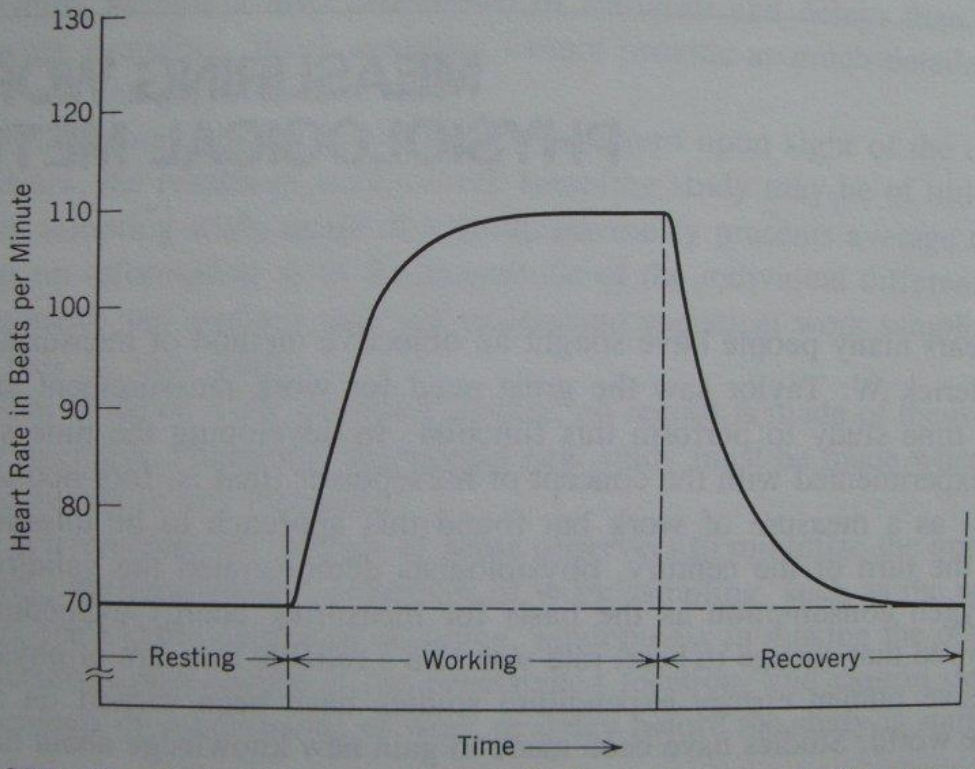

Figure 254 Heart rate in beats per minute before, during, and after physical work.

Heart Rate Measurement:

- The increase in heart rate during work may be used as an index of the physiological cost of the job. Also the rate of recovery immediately after work stops can be utilized in some cases in evaluating physiological cost.
- The total physiological cost of a task consists not only of the energy expenditure during work but also the energy expenditure above the resting rate during the recovery period, that is, until recovery is complete.
- Each time heart beats, a small electric potential is generated. By placing electrodes on either side of the chest, this potential can be picked up and transmitted by wire or by radio transmitter to a receiver. There the individual heart beat can be counted directly, or by means of cardiotachometer the impulsives can be converted into heart rate, that is, heart beats per minute.

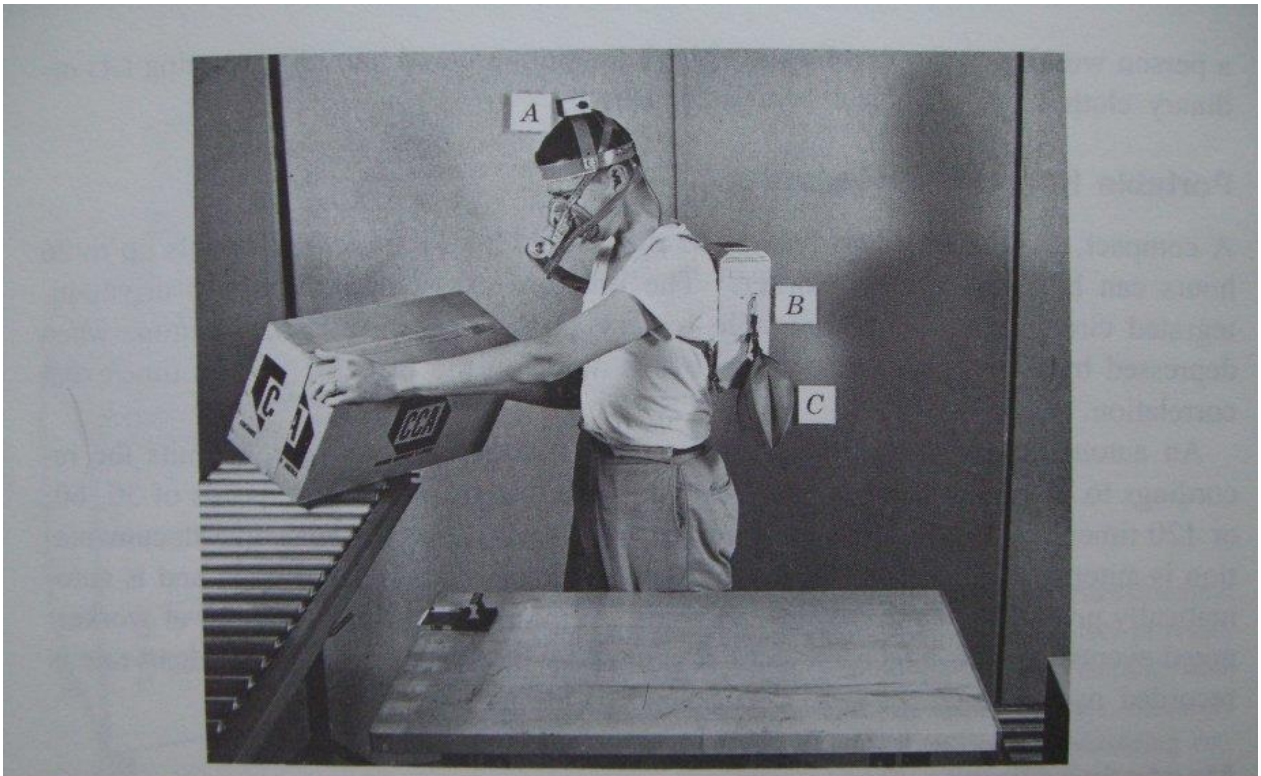

Figure 255 Apparatus for measuring heart beat and oxygen consumption. *A*, transmitter for telemetering heart beats; *B*, respirometer for measuring volume of exhaled air; *C*, rubber football bladder for collecting random sample of exhaled air.

- Heart beat signals can also be obtained by means of an ear lobe unit. This apparatus consists of a photo duodiode placed behind the ear and illuminated by a light source mounted on the other

side of the ear. The opacity (not letting the light through) of the ear lobe changes as the blood surges through the ear with each heart beat. The impulse created by each heart beat can be transmitted by wire or radio transmitter and recorded.

- Information concerning rate of recovery also cen be obtained simply by using a stethoscope and stop watch.

Measuring Oxygen Consumption:

- A common method of obtaining this information is by means of a portable respirometer. The respirometer indicated directly the volume of exhaled air in liters. A sample of the exhaled air is drawn off at random intervals into a rubber football blader, and analysis of its content is made. This permits a comparison of the oxygen content of the sample of expired air with that of the air in the room.

Use of Physiological Measurements in Work Methods:

When a new plant and its production facilities are being designed or purchased, management is often confronted with the problem of whether a person can physically perform a particular operation, or how best to organize the work for each person when a group is needed to do the job, or how much rest will be required by a worker performing a specific task. The objective is to design the work method so that the operator can perform the task 8 hours per day, 5 days per week, without undue fatigue. Physiological measurements of the worker on the actual job or on a simulated operation can provide useful information pertaining to such problems.

Individual Differences:

- There is a great difference in the ability of individuals to perform muscular work.
- The capacity to withstand the stress of hard physical work is greater in the fit than in the unfit.

Practice & Fitness for Job:

- A well-trained male worker who is physically fit and suited to his job might be expected to expend approximately 5 kcalories per minute, or 2400 kclaries per 8-hour day, on his job.
- The physiological cost to this same man as a beginner on the same job would be greater if he attempted to produce the same number of product per day.
- Practice enables the worker to do a job with a lower expenditure of energy. Moreover, the better trained the worker is, the sooner the heart rate will return to the resting level after he stops work.

Physiological Cost of Walking:

- Studies of energy expenditure in walking have been made by many different investigators.

- Results of these studies indicate that for speed of 2-4 miles/hour energy expended in kcalories per minute is linearly proportional to the speed of walking in miles per hour.
- Assuming a metabolic cost at the resting state to be 1.2 kcalories per minute, then the relationship can be expressed by the equation

$$C = 1.0V + 1.2$$

C = kcalories/minute

V = speed in miles/hour

- However, energy expenditure is also proportional to body weight.

$$C = 0.047W + 1.02$$

C = kcalories/minute

W = weight (kg)

Establishing Time Standards by Physiological Methods:

- Physiological measurements can be used to compare the energy cost on a job for which there is a satisfactory time standard, but the comparison should be made for the same person.
- For example, if handling 10-pound cartons at the rate of 12 cartons/minute was considered normal performance, and if energy cost for that worker was 5 kcalories/minute, the answer to the question of what the time standard should be for handling 15-pound cartons under the same conditions might be obained by having the same worker handle 15-pound cartons at various speed, and then selectig the speed that gave an energy cost of 5 kcalories per minute.
- Thus the energy cost of the two jobs would be similar and the time standard can be determined.

Classification of Workloads:

Table 65. Classification of Work Loads in Terms of Physiological Reactions

Work Load	Oxygen Consumption in Liters per Minute	Energy Expenditure in Calories per Minute	Heart Rate During Work in Beats per Minute
Light	0.5–1.0	2.5– 5.0	60–100
Moderate	1.0–1.5	5.0– 7.5	100–125
Heavy	1.5–2.0	7.5–10.0	125–150
Very heavy	2.0–2.5	10.0–12.5	150–175

Results of research and experience in industry support the following statements as to the acceptable physiological cost of full body muscular work over an 8 hour day:

1) For the average male worker a maximum average energy expenditure of 5 kcalories per minute – a maximum average heart rate of 115 to 120 beats per minute.

2) For the average female worker a maximum average energy expenditure of 4 kcalories per minute – a maximum average heart rate of 115 to 120 beats per minute.