University of Michigan
Center For Ergonomics

Energy Expenditure Prediction Program™
Version 2.0

The Center for Ergonomics at the University of Michigan College of Engineering has developed programs for analyzing manual materials-handling tasks. These programs are in use at over 2000 U.S. and international sites by ergonomists, engineers, loss-control specialists, physical and occupational therapists, researchers, and others who evaluate and design jobs.

Installation

To install the Energy Expenditure Prediction Program insert the CD, open it, and read the install.txt file if necessary. Be sure to be signed on to the windows system as an administrator. To start the installation run the EEPP application file (EEPP.exe) and follow the directions. More information is found in the install.txt file.

Problems?

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What is the Energy Expenditure Prediction Program (EEPP)?

The Energy Expenditure Prediction Program™ (EEPP) is a software tool to estimate energy expenditure rates for materials handling tasks to help assure worker safety and health.

EEPP is based on the assumption that a job can be divided into simple tasks (activity elements) and that the average metabolic energy rate of the job can be predicted by knowing the energy expenditure of the simple tasks and the time duration of the task. The EEPP software is a user-friendly tool. It is more accurate than selecting values from a standard table and is more feasible and less costly than laboratory techniques involving measurement of oxygen consumption. It is useful in designing new jobs, comparing one job to another, and improving an existing job by identifying the particular tasks that require excess energy expenditure. The EEPP software provides an objective rate to gauge fatigue, which can also be compared with NIOSH guidelines.

Why should you use the EEPP?

The EEPP software -

- is easy to understand and apply to your materials handling jobs,
- is non-technical in operation,
- provides objective values to gauge worker safety, make comparisons, and design improvements,
- is less expensive and often more feasible than laboratory techniques,
- is more accurate than pulling standard energy expenditure values from published tabular data, and
- provides a summary value to compare with NIOSH guidelines.

Background Information

The University of Michigan's Energy Expenditure Prediction Program™ (EEPP) predicts metabolic energy expenditure rates by summing up the energy requirements of small, well-defined work tasks that comprise the entire job. The resulting estimate is much more precise than a single table value depicting an entire job, and the required job analysis procedure is accordingly more tedious, but computerization (e.g. EEPP) has made this type of analysis feasible. This method allows energy expenditure analysis of existing jobs as well as simulated, non-existent jobs. This ability to simulate workplaces is important in the job design process. This method also identifies specific work tasks that contribute heavily to an overall high job energy expenditure rate, which facilitates job redesign activities.

The metabolic prediction model (Garg et al., 1978) is based on the assumption that a job can be divided into tasks or activity elements. The energy expenditure requirements for each task can be added together to determine the energy expenditure of the entire job. The energy expenditures of the tasks are calculated using prediction equations derived from empirical data. The information for each task needed to compute these energy requirements include: force exerted, distance moved, frequency, task posture, lifting technique for lifting tasks, and the time needed to perform the tasks. Gender and body weight, two worker factors, are also needed. The average metabolic energy expenditure rate for the job is then predicted as the average (over time) of the sum of the energy requirements of the individual tasks, plus the energy required to maintain various body postures. The prediction model is described by the following equation:

$$E_{job} = E_{basal} + S(E_{taskj} / T_{taskj})$$

where:

E_{job} = average energy expenditure rate of the job (Kcal/min)

E_{basal} = metabolic energy expenditure rate necessary to maintain basal metabolism and posture (Kcal/min)

E_{taskj} = net metabolic energy expenditure of the j^{th} task in steady state (Kcal)

T_{taskj} = time duration of the j^{th} task (min.)

As the equation shows, the energy expenditure prediction model has two basic components.

(1) Energy expenditure necessary to maintain non-work related body energy requirements, and

(2) Net energy requirements of the various work tasks.

The first component depends upon the energy required for posture maintenance. The energy requirement is a function of gender, body weight, and body posture. The model can accommodate three different body postures: standing, standing bent over and sitting.

The second component is the net metabolic energy expenditures for the various tasks that comprise the entire job. The model accommodates many different work tasks, including both static and dynamic work. The prediction of the energy expenditure of the separate tasks is a function of various factors, as was previously mentioned. Much of the data needed for this methodology can be collected from industrial engineering time and motion studies or from predetermined time systems. Niebel (1982) provides further information.

The accuracy of this prediction procedure depends upon several factors, including:

(1) The completeness and accuracy of the division of the job into tasks (the job analysis must be correct);

(2) The availability of a prediction equation that precisely describes the task that has been identified;

(3) The accuracy of the task equation itself.

Program Inputs

Subject's gender and weight;
List of activity elements (e.g. lift, push, carry); and
Parameters specific to activity elements (e.g. frequency, weight of load, distance carried).

Program Outputs

Listing of activity elements with their corresponding energy expenditure;
Calculation of the total energy expenditure rate for the job in Kcal/minute or METS; and
Data can be viewed on screen, printed, or written to a file for later recall or for inclusion in a report.

Task Elements

Posture Tasks:

- Standing
- Standing bent
- Sitting

Incremental Tasks:

- Lifts or lowers:
    - Stoop - knees straight, back bent
    - Squat - knees bent, back straight
    - Semisquat - knees and back bent
    - Arm lift - Hands above 32 inches
    - One handed - Hands above 32 inches
- Walks:
    - Level surface
    - Inclined surface
- Carries or holds:
    - Arms length at sides
    - Against waist at sides
- Pushes or pulls:
    - Horizontal direction
    - Forward direction
- Hand work - General:
    - Light (writing)

Heavy (gear assembly)

Arm work - Lateral:

180 degrees - one or both hands

90 degrees - standing

90 degrees - sitting one or both hands

Arm work - Horizontal:

Standing

Sitting

Arm work - General:

Light one hand (filing metal)

Light both hands (planing wood)

Heavy one hand (hammering nails)

Heavy both hands (upholstering)

EEPP Example Application

The following job analysis presents an example illustrating the performance of the EEPP software.

Step 1: Determine task work elements.

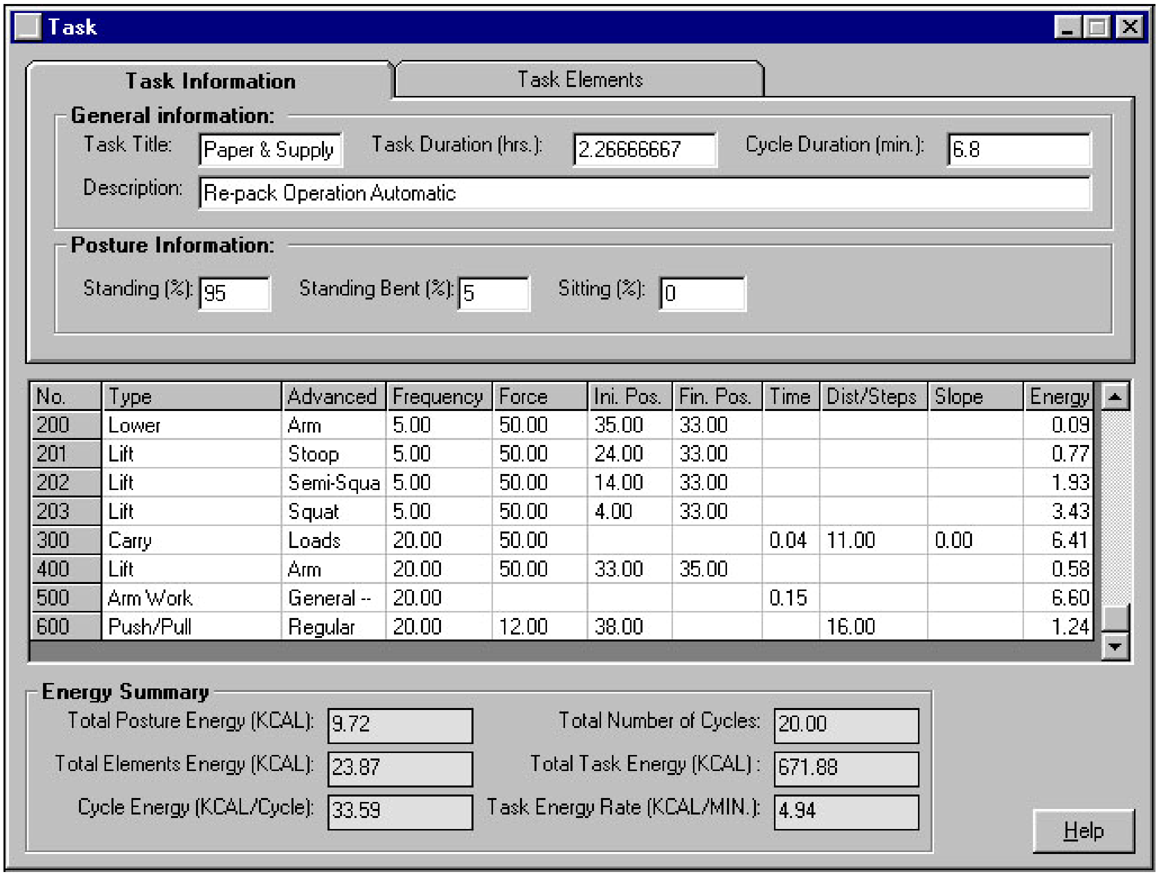
The Paper and Supply Co. repackages cases of copy machine paper. Workers must carry the cases from a pallet to a worktable, remove the paper from the cases, and push the reams onto a conveyor. One work cycle, defined as the time to process an entire pallet of 20 cases stacked in 4 tiers, takes 6.8 minutes. Each case is 50 lbs. and is 10" high. The worker is male, weighs 130 lbs., and has a carry height of 33". The average time it takes him to walk 11 feet from the 35" high worktable to the 4" high pallet is 0.04 minutes. It takes 0.15 minutes to unload a case. A 12 lb. push force is necessary to move the paper the 16" across the table onto the conveyor.

Task work elements:

1. Walk to pallet
2. Lift case of paper from pallet
3. Carry to work table
4. Place case on worktable
5. Remove paper from case
6. Push paper onto conveyor

Step 2: Enter data into EEPP.

The following screenshot illustrates EEPP after the data has been entered.



No.	Type	Advanced	Frequency	Force	Ini. Pos.	Fin. Pos.	Time	Dist/Steps	Slope	Energy
200	Lower	Arm	5.00	50.00	35.00	33.00				0.09
201	Lift	Stoop	5.00	50.00	24.00	33.00				0.77
202	Lift	Semi-Squa	5.00	50.00	14.00	33.00				1.93
203	Lift	Squat	5.00	50.00	4.00	33.00				3.43
300	Carry	Loads	20.00	50.00			0.04	11.00	0.00	6.41
400	Lift	Arm	20.00	50.00	33.00	35.00				0.58
500	Arm Work	General --	20.00				0.15			6.60
600	Push/Pull	Regular	20.00	12.00	38.00			16.00		1.24

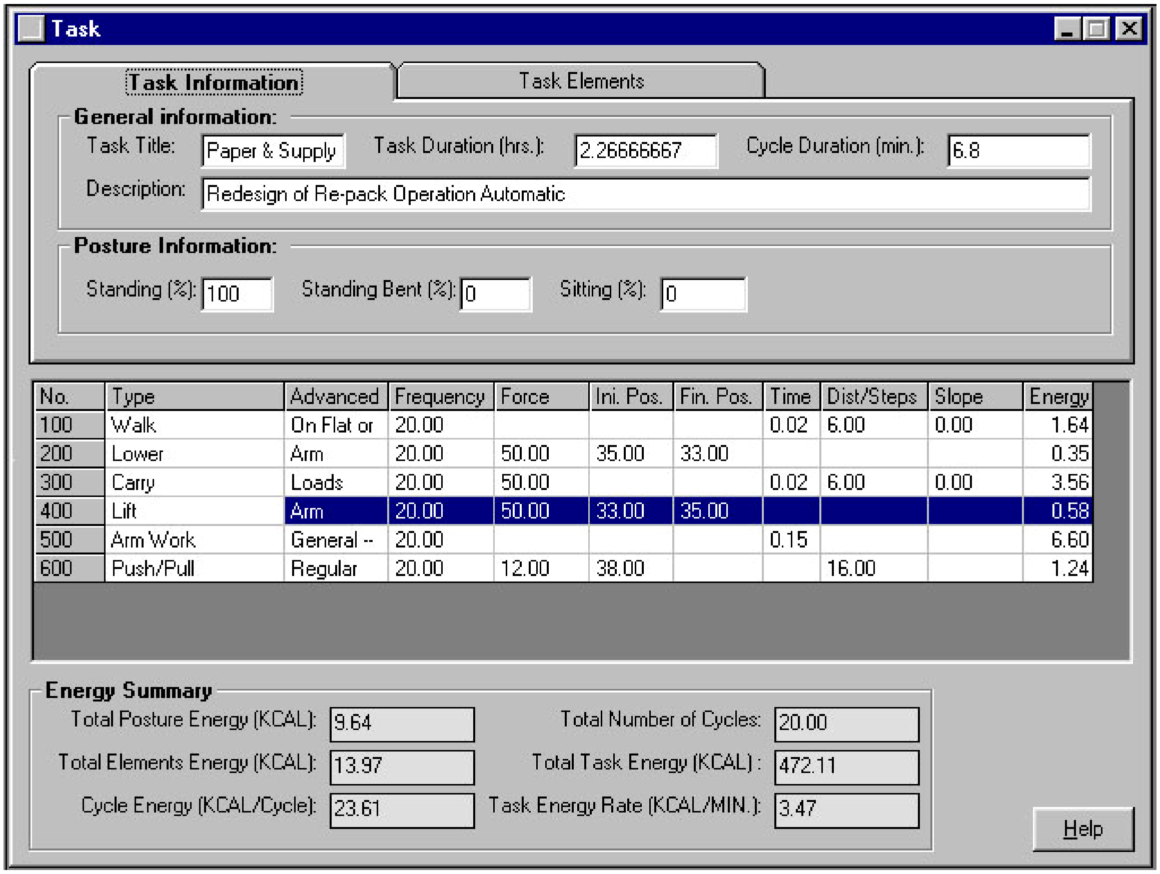
Step 3: Perform the Analysis of Output and Job redesign.

A glance at the summary energy expenditure rate of 4.94 kcal/min at the bottom of the screenshot above alerts the safety engineer that the job is too fatiguing. It significantly exceeds the 3.5 kcal/min action limit guideline for an average 8-hour day set by the National Institute for Occupational Safety and Health (NIOSH).

The right hand column above indicates that it is more arduous to lift cases from the lower levels on the pallet. Carrying the cases to the workstation is also a high fatigue factor.

The safety engineer redesigns the job by installing an automatic pallet lift device that will eliminate the worker's need to bend when he lifts. With the new device, all cases can now be lifted at the same optimum height. The job is also changed by moving the pallet closer to the worktable. The worker's walk distance is reduced to 6 feet.

Data from the job changes are entered into the program resulting in the following screenshot:



No.	Type	Advanced	Frequency	Force	Ini. Pos.	Fin. Pos.	Time	Dist/Steps	Slope	Energy
100	Walk	On Flat or	20.00				0.02	6.00	0.00	1.64
200	Lower	Arm	20.00	50.00	35.00	33.00				0.35
300	Carry	Loads	20.00	50.00			0.02	6.00	0.00	3.56
400	Lift	Arm	20.00	50.00	33.00	35.00				0.58
500	Arm Work	General --	20.00				0.15			6.60
600	Push/Pull	Regular	20.00	12.00	38.00			16.00		1.24

The energy expenditure rate has been reduced to an acceptable 3.47 kcal/min. Based upon NIOSH data, the safety engineer could expect 75% of women and 99% of men to be able to perform the job with only nominal risk. Administrative controls such as designated rest breaks would reduce the risk even further.

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