Design of Dynamic Work

Estimation of Metabolic Rate
- ISO Components Method
- MVMA Method of Bernard and Joseph
- Manual Materials Handling
- External Work Method

Estimation of Maximum Aerobic Capacity
- Distributions of Maximum Aerobic Capacities
- Table of Design Goals

Estimation of Endurance Time

Estimation of Recovery Time

Estimation of Metabolic Rate

Adapted from ISO Components Method

Components	**Initial Data**	**Values**	**Rate of Energy Expenditure [W]**
Base	---	---	80
Posture	Sit Stand	20 45	
Activity	Body Involvement N H 1A 2A WB	See Activity Matrix	
	Effort L M H VH		
Horizontal Rate of Travel - Average in Feet / Min	Estimate [ft/min]: 2.5 mph = 220 ft/min	1.0 x Rate [ft/min]	
Vertical Rate of Travel - Average in Feet / Min	Estimate [ft/min]: 1 step / 2 sec = 15 ft/min (ie, 6-inch step)	17 x Rate [ft/min]	
		Total Metabolic Rate (Sum the Last Column)	

	Effort			
Activity	Light	Moderate	Heavy	Very Heavy
None	0	0	0	0
Hand(s) Only	25	55	70	80
One Arm	65	100	135	170
Both Arms	115	155	190	230
Whole Body	225	340	505	700
	Can be performed indefinitely with ease	Can be performed indefinitely with some effort	Can be performed for 30 - 60 min before a break	Can be performed for about 15 min before a break

Estimation of Metabolic Rate

Adapted from the MVMA Qualitative Method of Bernard and Joseph

Components	**Initial Data**	**Values**	**Rate of Energy Expenditure [W]**
Base	---	---	100
Arms	AI (for use with Lift) 0: Sedentary 0: Little Hand/Arm Movement 1: Hands Move Mostly < 20 in 2: Frequently Hands Move > 20 in 3: Bend, stoop, extended reaches	 0 69 98 127 156	
Lift (not appropriate for heavy manual materials handling)	Weight of Parts and Tools [lb] Wt: < 4 4 to 11 > 11 WI: 1 2 3 Frequency [cycles / min] Frq: < 2 2 to 5 > 5 FI: 1 2 3	AI x WI x FI x 5.1	
Walk - Average in Feet / Min (Do not include push / pull)	Estimated Rate [ft/min]: 2.5 mph = 220 ft/min	1.0 x Rate [ft/min]	
Push / Pull	Average Force [lb] = ________ {F} Average Distance per Minute [ft/min] = ________ {D}	(6 + 1.3 x F) x D / 3	
Vertical Rate of Travel - Average in Feet / Min	Estimated Rate [ft/min]: 1 step / 2 sec = 15 ft/min (ie, 6-inch step)	17 x Rate [ft/min]	
		Total Metabolic Rate (Sum the Last Column)	

Estimation of Metabolic Rate for Materials Handling Tasks

Adapted from Garg and NIOSH

L = average load in pounds

Freq = average lifting rate in lifts per minute

M = metabolic rate in watts [W]

Lifting that requires a stoop (e.g., below the waist)
M[W] = 117 + (12.9 + 0.46 L[lb]) x Freq [lifts/min]

Lifting that predominately involves arms (e.g., above the waist)
M[W] = 117 + (2.14 + 0.66 L[lb]) x Freq [lifts/min]

Estimation of Metabolic Rate for External Work by Arms or Legs

Adapted from Kamon

Not applicable to pushing or pulling while walking

W_{ex} = external work rate estimated as the force in pounds times the average rate of distance moved or applied = F_{ex} x D_{ex} [ft lb / min]

F_{ex} = average force applied or exerted in pounds [lb]

D_{ex} = average distance in feet that object is moved in one minute [ft/min]

M = metabolic rate in watts [W]

$M[W] = 104 + 0.095\ W_{ex} = 104 + 0.095\ F_{ex} \times D_{ex}$

Estimation of Maximum Aerobic Capacity (MAC)

Adapted from Kodak

Distributions of Maximum Aerobic Capacity

Men
MAC = 38 ± 7 [mL/kg.min]
MAC = 1100 ± 200 [W] based on average weight of 83 kg

Women
MAC = 31 ± 6 [mL/kg.min]
MAC = 720 ± 140 [W] based on average weight of 66 kg

Maximum Aerobic Capacity in Watts

	Percentile				
Population	5^{th}	25^{th}	50^{th}	75^{th}	95^{th}
Men	770	965	1100	1235	1430
Women	490	625	720	810	945
50/50 Mix	535	710	875	1100	1360

Note: If the metabolic rate is predominately driven by upper body efforts and no involvement of the legs, then you may wish to consider reducing the MAC by 30%. That is, the MAC_{upper} = 0.7 MAC.

Design Goal: Maximum Aerobic Capacities for Least Fit Workers

Source	mL/kg.min	kcal/h	Watts
Kodak	27	570	660
NIOSH Whole Body	27	560	660
NIOSH Upper Body	19	400	460

Assumes an average body weight of 70 kg.
Experience indicates that using a value greater than the 5^{th} %ile is protective of most workers.

Endurance Time [min] versus
Percent Maximum Aerobic Capacity [%MAC]
From Bernard and Kenney

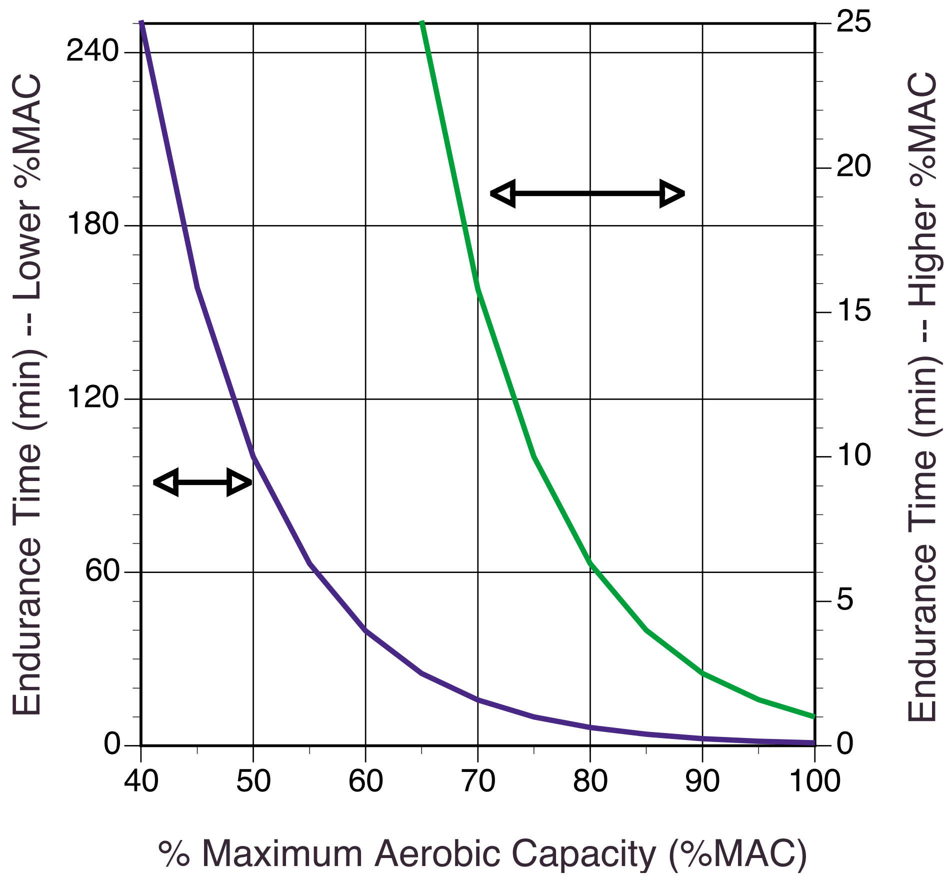
%MAC = (Metabolic Rate / Maximum Aerobic Capacity) x 100%
%MAC = 100% M / MAC

For a %MAC, either for an individual or for a design limit, the endurance (maximum work) time is read either from the left axis and the left curve for %MAC between 40 and 65% or from the right axis and right curve for %MAC from 65% to 100%.

For a required work time, the greatest %MAC is read by starting from the left axis for time between 25 and 250 min to the left curve or from the right axis to the right curve for times less than 25 min.

t_{end} [min] = 10^(4 - 4 %MAC/100%)

(This endurance time represents a minimum value for a population at a given %MAC.)



Recovery Time [min] versus Work Time [min] and Percent Maximum Aerobic Capacity [%MAC]

For a specific work time read up to the %MAC curve, either for an individual or for a design capacity, and read the minimum required recovery time [min].

This family of curves can also be used (1) to specify the maximum work time for an allowed recovery time at a specific %MAC or (2) to specify a maximum %MAC for a given work time and recovery time. Generally, the curves stop near the endurance time for a specific %MAC curve.

These curves assume an 8-hour work day and use the accepted limit of 33% maximum aerobic capacity for an 8-hour day.

t_{rec} [min] = t_{work} (%MAC/100% - 0.33) / 0.23