HeatCommander™

PPE Heat Stress Calculator

USER MANUAL

HEATCOMMANDER™

Developed by:

GEOMET Technologies, LLC

Developed under sponsorship of the Technical Support Working Group (TSWG)

Version 1.3

July 2007

TABLE OF CONTENTS

LOADING THE SOFTWARE

After the self-extracting file (**HCextract.exe**) has been downloaded, its contents can be extracted to a folder of the user's choice on a PC.

Before loading the software onto a PDA, the user must establish a communication link between the PDA and the PC (e.g., via a Guest Partnership using Microsoft ActiveSync).

Installation is then accomplished by running the file **Install.bat**. The installation process takes less than a minute.

The application is launched on the PDA by clicking on the **HeatCommander** icon that appears in the **Programs** area.

Should the PDA lose all its power, the application will need to be reloaded (exception – on some PDAs the application may remain if installed to flash memory).

ACTIVATING THE SOFTWARE

After loading the software you will need to activate it in order to access the program. On the PDA, hit Start, then Programs, then HeatCommander. On the opening screen, depress the Continue button. You will then be prompted for a Serial Number, Unlock Code and Activation Code.

Enter the Serial Number that you received when you purchased HeatCommander™ and then depress the Generate Unlock Code button. Next, go to the following website:

http://heatcommander.net/activate

At this site, you will be prompted for the Serial Number and Unlock Code. Take care to enter them accurately. Next, press the Activate button – you will be provided with an Activation Code.

Return to the PDA, enter the Activation Code, and depress the Activate button. If you made no entry errors at the website and on the PDA, you should see a message that the application has been successfully activated.

Should you need to reload the application at a later date (e.g., due to the PDA losing all its power), you may need to go though the activation process again. NOTE – With a single-user license, the number of allowable activations is limited to two.

SOFTWARE LICENSING AGREEMENT TERMS AND CONDITIONS

GEOMET TECHNOLOGIES, LLC (*A Versar Company*)

HeatCommander™ – PPE Heat Stress Calculator

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HeatCommander™ is a software application that runs on a personal digital assistant (PDA) with a PocketPC operating system. The application determines acceptable stay time (i.e., time spent in personal protective equipment or PPE), from the standpoint of avoiding heat exhaustion and excessive dehydration, for various combinations of individual characteristics, type of PPE, activity level, and surrounding environment.

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- The loan, publication, transfer of possession (whether by sale, exchange, gift, operation of law or otherwise), sublicensing, rental, or other dissemination or use of the Software, in whole or in part, to or for any third party.
- Reverse engineering, decompiling, translation, disassembling, or otherwise attempting to discover the source code of the Software.
- Modifying, altering, adapting, or merging the Software.

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GEOMET warrants that the Software will conform substantially to the associated documentation (User Manual) provided by GEOMET with the Software. GEOMET does not warrant that the

Software will be error free or that it will operate in conjunction with other equipment, software or services that may be obtained by Buyer. GEOMET's sole and exclusive liability for insuring performance of the Software will be to provide Software Corrections. However, if GEOMET is unable to provide Software Corrections, then as Buyer's sole and exclusive remedy GEOMET will grant Buyer a credit or refund, at Buyer's option, for the Software involved and accept its return.

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- Installation of the Software;
- Basic functionality of the Software as described in the User Manual; and
- Installation of updates to the Software.

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- Buyer's inquiries relate to business practice, application consulting or training;
- Buyer's use of the Software is outside that set out in the User Manual;
- Buyer's use of Support Services is excessive, abusive or fraudulent;
- Buyer is not using the current release of the Software or its immediate predecessor; or
- Buyer has breached the Terms and Conditions described herein.

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GEOMET may, from time to time, provide Software updates via the www.heatcommander.net website (or such successor URL as GEOMET may provide). Any such updates within 12 months after the Software Purchase Date will be provided at no cost to Buyer. Buyer is responsible for checking the website periodically to determine the availability of updates and for installation and implementation of any updates and associated data conversion. Three months after the availability of any new release/version, support services for any previous releases/versions will cease.

1. BACKGROUND AND OVERVIEW

This section provides a brief background on the project that led to the development of HeatCommander™. It also describes the purpose and limitations of the software and provides an overview of the application along with some heat stress fundamentals.

1.1 Background

First responders to emergency situations must be concerned not only with the hazardous agents they face but also with such issues as heat stress when wearing personal protective equipment (PPE). Both military and civilian users have an urgent need for a quick way to determine acceptable stay time (i.e., time spent in PPE) while wearing PPE, to avoid excessive heat stress that can threaten their ability to function as well as their health and safety. An optimal approach must include (1) accurate prediction of acceptable stay times for specific situations, and (2) ease of use by first responders, including a user-friendly interface that provides help in choosing inputs.

Current approaches to determination of acceptable stay times are limited by insufficient accuracy and by a tendency to "err on the safe side." That is, the stay-time estimate tends to be conservative, requiring the responder to cease work prematurely and remove the PPE. At the same time, care must be taken to avoid an overly aggressive approach yielding an estimate that could threaten the responder's health or safety. An optimal approach is one that provides an accurate, risk-balanced estimate of the stay time, yet is not overly cumbersome for the user to provide appropriate input values.

HeatCommander™ has been developed by GEOMET as a usable, relatively simple solution to the heat-stress problem that can be

implemented on a personal digital assistant (PDA) device. Key elements of the approach are as follows:

- Development and initial evaluation of a robust, yet relatively straightforward, set of algorithms for prediction of time-dependent heat stress for specific combinations of (1) individual characteristics, (2) PPE worn, (3) work levels, and (4) ambient environments, to determine risk levels for various stay times, and the maximal stay time to avoid excessive stress.
- Implementation of the algorithm on a PDA, with a user interface that includes input menus and provides built-in help for choosing appropriate values for these four inputs.

1.2 Software Purpose and Limitations

HeatCommander™ is intended to provide an estimate of "maximum stay time" for a specific situation defined by (1) the characteristics of an individual wearing PPE, (2) the PPE or other clothing that is worn, (3) the activity or task that is being performed, and (4) the prevailing environmental conditions. The maximum acceptable stay time for a given situation is estimated by jointly considering the risks of heat stress, dehydration and physical exhaustion.

All emergency response workers, both military and civilian, share the problem of heat stress. Due to the extreme dangers of heat injury, which has caused numerous deaths in athletes, workers and soldiers, conservative work practices and limits have been developed to control the risk. However, such limits usually will severely reduce the productivity of responders, to the point that requisite training and critical missions cannot be accomplished; consequently, the limits often are ignored, and responders continue to work until they suffer heat exhaustion collapse or fatal heat stroke.

The more accurate predictions possible from this application will enable users to allow work for longer periods when necessary and, thus, extend stay times to help complete missions while being aware of the risk.

The estimates provided by HeatCommander™ have been evaluated based on human subject testing of U.S. Marines and firefighters under controlled working and environmental conditions in a chamber setting. While the application is intended to extend the stay time without causing unreasonable risk, no guarantee to that effect can be made – primarily because of the variability in individuals' physical conditions. For example, the estimate of acceptable stay time may not be applicable for an individual who is physically "out of shape," who has a relatively high (> 26) Body Mass Index (BMI) value, or who has some underlying respiratory or heart condition. The BMI value is calculated as follows: BMI = kg/m^2, where kg is weight in kilograms and m is height in meters.

Thus, as noted previously, it is expressly understood that users of HeatCommander™ are doing so at their own risk.

1.3 Software Overview and Basis

Figure 1-1 shows the opening screen for the application. After pressing Continue, the main input screen (Figure 1-2) will appear. As described below, heat stress is primarily a function of four factors – individual characteristics, activity level, type of PPE and the local environment – and inputs are required for each of these factors. Any set of inputs provided by the user can be saved for future editing or use. Once all inputs have been provided, the user proceeds to the next step – Calculate – at which point outputs are provided by the application.

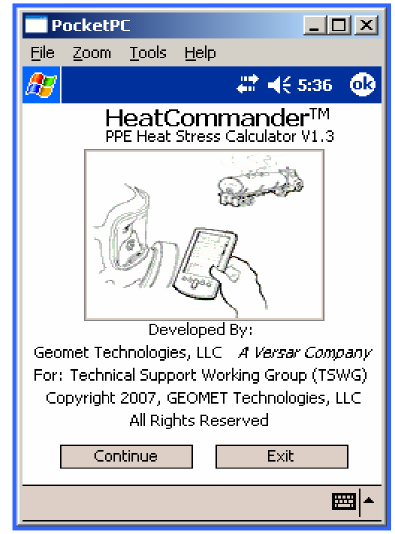

Figure 1-1. Opening Screen.

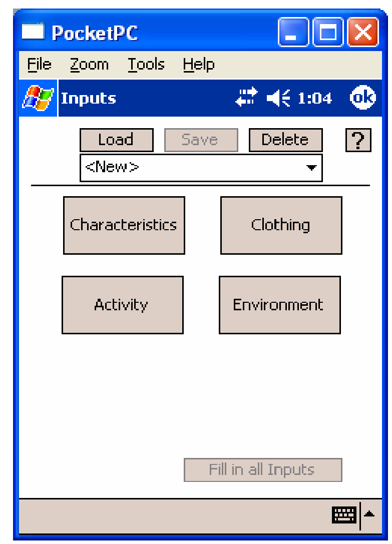

Figure 1-2. Main Input Screen.

The basic factors affecting human heat production and exchange (Figure 1-3) bear a close resemblance to the main input headings in Figure 1-2. As a general rule, human deep body temperature remains relatively constant at about 37 ºC (98.6 ºF) and skin temperature averages from 33 ºC (~91 ºF), when an individual is clothed normally for the surrounding conditions and is sedentary, to ~35 ºC (95 ºF) when active and beginning to sweat..

When an individual is working, body temperature starts to rise at a rate that depends on the worker's physical characteristics, the PPE worn, the activity level or work rate, and the surrounding environment. The heat produced is manifested initially in elevated skin temperature and ultimately in elevated core body temperature as well; any heat produced that is not exchanged with (i.e., lost to) the surrounding environment must be stored in the body.

The rate of heat exchange is governed primarily by clothing insulation (in clo units) and, when sweat evaporation is required, by moisture permeability (I_m, an index ranging from 0 to 1); the rate can be characterized by the I_m/clo ratio and the characteristics of the surrounding environment. For example, if the surrounding air temperature is lower than the skin temperature, some heat can be lost through convective and radiant ("dry") heat transfer (heat also can be gained in the same manner, if the air or radiant temperature is greater than skin temperature).

When heat is being stored in the body, the thermal balance is upset unless physiologic changes occur that bring the body temperature into balance. For example, blood flow is increased to the skin surface to increase heat loss to the surrounding environment and, if that is insufficient (i.e., under hot conditions), then sweating is induced in an attempt to cool the body by evaporative heat exchange.

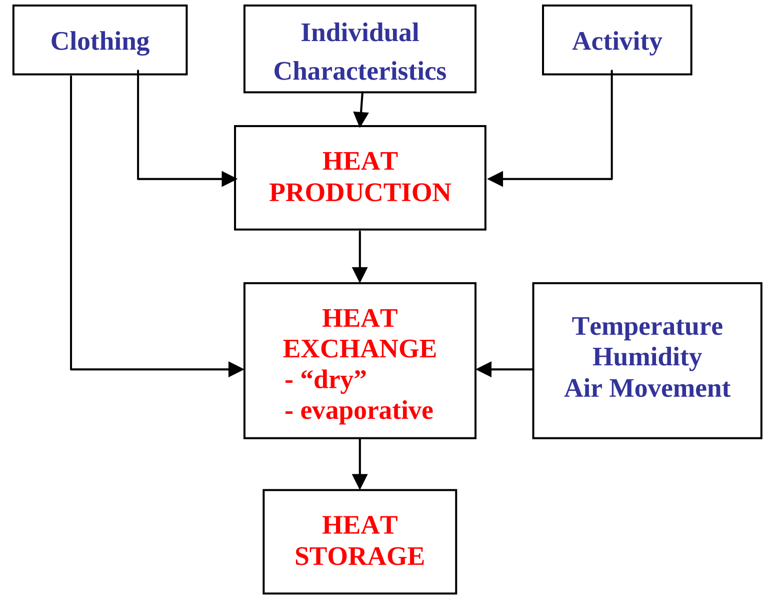

Figure 1-3. Factors Affecting Heat Production and Exchange.

The body's initial response to excessive heat storage – heat discomfort, and distraction – usually is followed by increasing fatigue. The next stage includes dehydration, sometimes with debilitating muscle cramps as a result of loss of key electrolytes, and heat exhaustion, characterized by severe fatigue, nausea, headaches and collapse as a result of inadequate circulation of oxygen to the brain (as well as the rest of the body). The final stage of the progression – heat stroke – is characterized by hyperthermia (i.e., deep body temperature elevated to a level above 106 ºF, which can result in cessation of sweating, onset of shivering, and/or reduction of blood flow to the skin/brain and often is fatal). In a hazardous environment where the worker needs to be moved to a contaminant-free area before the PPE can be safely removed, the risk of attaining excessive heat storage is greatly increased, and the period of allowed exposure must be further limited.

2. INPUT SCREENS

This section explains each of the four input screens available in HeatCommander™, along with the main input screen that precedes them.

2.1 Main Input Screen (Loading and Saving)

The Main Input Screen (previously shown in Figure 1-2) serves primarily as a transition point, providing access to the individual input screens described below. It does, however, provide one other important function – loading or saving inputs.

Once inputs have been entered, it is recommended that they be saved. Saving is accomplished by simply pressing the Save button; the application automatically assigns a name to the saved profile, based on the individual's name (shown on the Characteristics Screen in Section 2.2) along with the date and time. Note that <New> should be displayed on the profile list when saving a file; otherwise, the application will ask whether you wish to overwrite the profile name that is currently displayed.

Loading previously saved entries also is straightforward. First, review the list of previously saved profiles, if any, by tapping ▼ to the right of <New>. Then select the profile you want and press the Load button. Once a profile has been chosen, the input screens shown later in this section will be populated with the values contained in that saved profile. After loading a profile you can proceed directly to the output screen, by hitting Calculate, or you can change some input values before calculating.

Similarly, to delete a previously saved profile, simply highlight that profile in the list and then press the Delete button.

2.2 Characteristics Screen

The inputs for this screen (see Figure 2-1) include ID, name, age height, weight, gender, and fitness level. As noted above, the name supplied here is used as part of the profile name, if you elect to save the inputs.

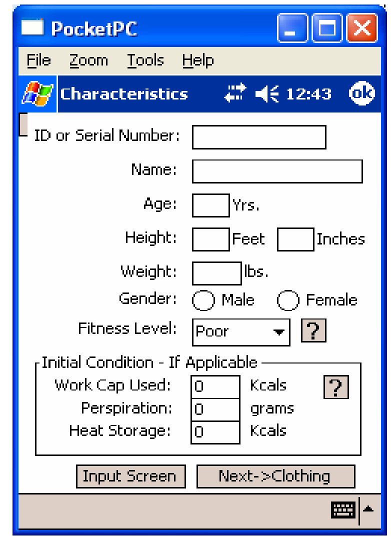

Figure 2-1. Characteristics Screen.

For input fields requiring data entry, you'll need to bring up the keyboard by clicking on the icon located at the lower-right part of the screen. Height can be entered as feet and inches (e.g., 5 feet, 10 inches) or simply as inches (e.g., 70 inches).

For fitness level, the choice Excellent should be reserved for extremely fit individuals (e.g., athletes, U.S. Marines), at an appropriate weight for their height (Body Mass Index < 26), who exercise regularly and have no cardiovascular or respiratory problems.

The last input area for this screen – Initial Condition – customarily is populated with zero values for Work Cap (work capacity) Used, Perspiration and Heat Storage. An exception occurs when the user wishes to examine the outcome for multiple, sequential tasks. After the first task has been performed and the user returns to the input screens, this input area will be populated with values that reflect the individual's state after completing that task. Further details regarding multiple tasks are provided in Section 4, and an example is given in Section 5.

2.3 Clothing Screen

The two inputs for this screen (see Figure 2-2) are insulation and permeability for the clothing ensemble worn by an individual. In the case of PPE ensembles, the input values reflect not only the protective gear but also the breathing apparatus.

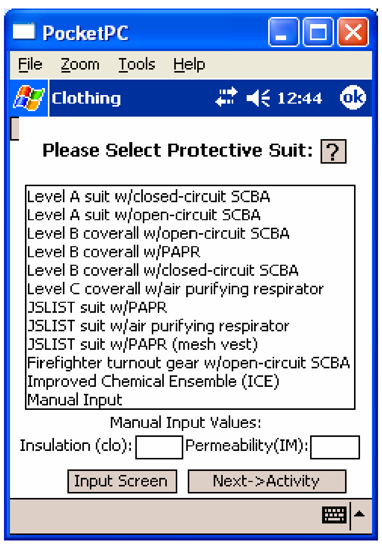

Figure 2-2. Clothing Screen.

The insulation value refers to the thermal resistance of the clothing, which affects heat transfer between the individual and surrounding environment. Permeability refers to the evaporative resistance of the clothing, which affects latent heat transfer from the skin through the clothing layer and evaporative heat loss from the skin surface. Clothing insulation normally is expressed using the unit "clo," where 1 clo = 0.155 m^2K/W. Permeability is measured by a moisture permeability index (I_m) – the ratio of the maximum evaporative cooling at a given ambient vapor pressure, from a 100% wetted surface through any clothing, to that of a psychometric wet bulb thermometer at the same vapor pressure.

Insulation and permeability values are provided on the input screen for 11 ensembles. The clo values are intrinsic (i.e., they do not include the clo for the external air layer surrounding a clothed body) and were determined through chamber tests under controlled environmental conditions with a thermal manikin.

Although default clo and I_m values are provided for a selected list of PPE ensembles, you also can choose Manual Input to provide your own values in the input areas below the list. However, there must be a reasonable basis for such values (thermal manikin testing is considered the only reliable method for accurate determination of clo and I_m values). The intrinsic clo value for ordinary indoor clothing (long-sleeve shirt and trousers, T-shirt and boxer shorts underwear, ankle socks and oxford shoes) is about 0.6 and the I_m value is about 0.45. At low air motion (e.g., < 0.5 mph), the external air layer surrounding the body contributes an additional 0.8 clo of insulation. Note that the Im value is not directly altered by air motion per se.

2.4 Activity Screen

The two inputs for this screen (see Figure 2-3) are the activity duration (in minutes) and the activity level (in Met). Met is a measure of the hourly rate of energy expenditure per unit of body surface area (in square meters; typically ~1.8 m^2). Various activity levels are provided for selection, ranging from sedentary (1 Met) and very light (2 Met) activities to severe (9 Met) and exhausting (10 Met) activities. As with insulation and permeability values for clothing (see Section 2.3), there is an option for manual input in an area below the activity list. Fractional values are allowed for the manual input (e.g., 3.25 Met). Note that, for an individual at "rest" when wearing PPE, the activity level is not 1 Met but rather ~1.2 Met, due to the added load (weight) of the PPE ensemble.

The estimate of acceptable stay time is quite sensitive to the Met level chosen; if uncertain, it is advisable to "err on the high side."

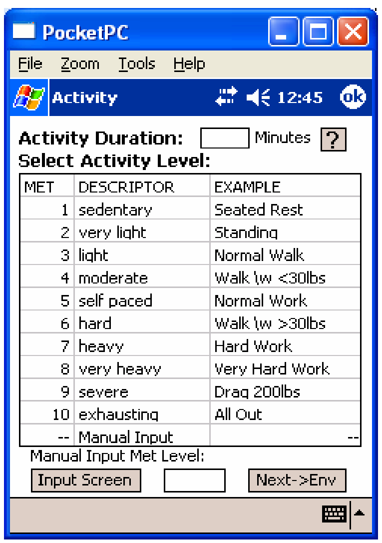

Figure 2-3. Activity Screen.

Energy expenditure is a function of body weight, weight of the load carried, walking/running speed, terrain and grade. The load carried includes the clothing worn by the individual. On a paved, level road and with essentially no load carried (e.g., light clothing), the energy expended would be about 2.4 Met when walking slowly (2.6 mph), 3.9 Met when walking moderately fast (3.75 mph), and 6.9 Met when walking very fast (5.3 mph).

2.5 Environment Screen

The four inputs for this screen (see Figure 2-4) are the temperature in the area occupied by the individual (in ºF), the relative humidity (in %), the wind speed (in mph), and the cloud cover (expressed as a fraction). The environmental conditions are assumed to be constant throughout the duration of the selected activity.

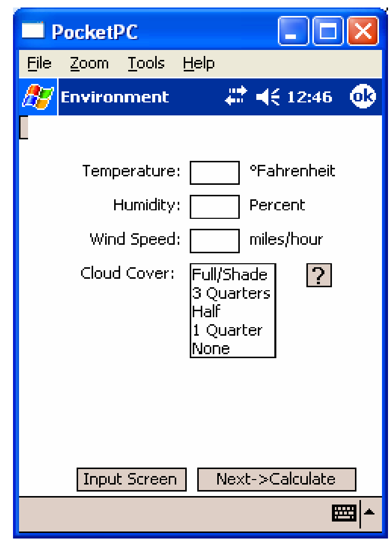

Figure 2-4. Environment Screen.

For the case of substantially changing environmental conditions, the user should consider using a series of sequential tasks (see Sections 4 and 5), bearing in mind that the body mass will cause significant lag in any body-temperature increase. A future version of HeatCommander™ that is under consideration will accommodate real-time weather inputs from attached sensors and will update the calculations and output at regular time intervals.

2.6 Embedded Help

Context-sensitive help is provided in various places in the application, in the form of a ? button. An example of the text that appears when accessing the embedded help, in this case for the Environment Screen, is shown in Figure 2-5. In cases where the help text is relatively long, it is divided into several dialog boxes (pressing ok will bring up the next dialog box).

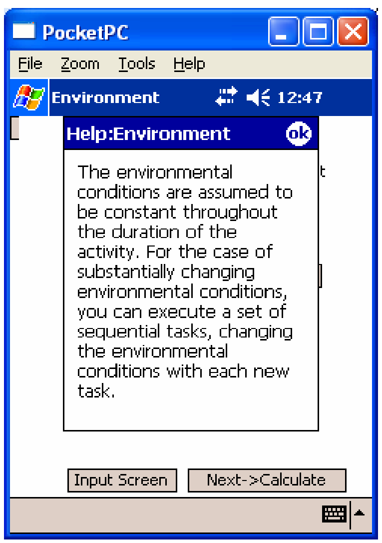

Figure 2-5. Example of Embedded Help.

3. OUTPUT SCREEN

After pressing the calculate button, the output shown in Figure 3-1 will be displayed. There are three types of outputs in the upper portion of the screen – Time to Work Exhaustion, Time to Dehydration Risk, and Time to 50% Heat Exhaustion Risk (i.e., 50% risk of heat exhaustion). If all three times are greater than or equal to the activity time (shown on the fourth line, 30 minutes for the example case in the figure), then the activity will be deemed **Acceptable**. If any of the three times is less than the activity time, then the activity will be deemed **Unacceptable**.

It is important to understand that the times to work exhaustion, dehydration risk, and heat exhaustion risk are estimated on the assumption that the individual begins the task immediately after donning protective gear. Thus, one should begin "clocking" the acceptable stay time from that point.

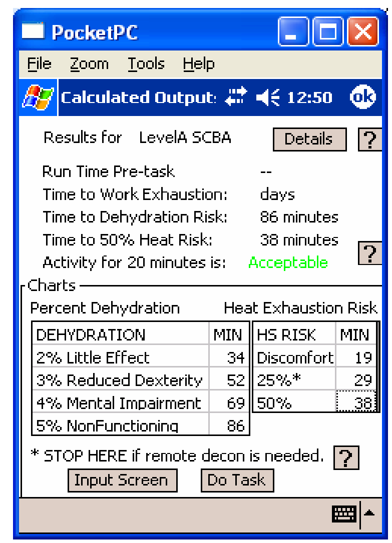

Figure 3-1. Output Screen.

Some additional details are shown in the charts on the lower half of the output screen. For example, the times to discomfort, 25% and 50% heat risk are shown on the lower right part of the screen. Pressing the Details button to the upper right (see Figure 3-1) causes the application to display further details on the lower part of the screen, such as percent of work capacity used, perspiration and heat storage (Figure 3-2). The output on the upper part of the screen remains unchanged. After the details are displayed, pressing the Charts button to the upper right causes the application to return to the chart view shown in Figure 3-1.

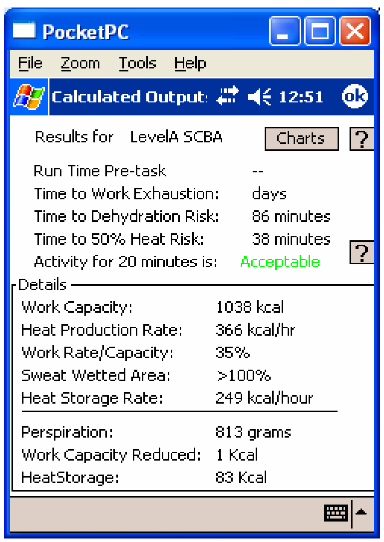

Figure 3-2. Output Screen after Pressing Details Button.

4. EXECUTING THE TASK

The user can execute the current task (see Section 4.1) and then continue with subsequent tasks (Section 4.2) if desired.

4.1 Current Task

The values shown on the output screen are not actually “assigned” by the application until the user presses the Do Task button at the bottom of the screen. At this point a message appears – Task executed for 30 minutes (for the example case in Figure 3-1). If the risk of heat exhaustion is 25% or greater, then the following message will appear – Heat Exhaustion Risk is over 25%, are you sure you want to do this task?

After executing the task and examining the output, you can exit the application or return to the Main Input Screen by pressing the Input Screen button at the bottom. At that point, you can save the current file, load a new file, or continue with subsequent tasks for the case that currently is loaded.

4.2 Subsequent Tasks

At this point the user has executed the current task and returned to the Main Input Screen. It is recommended that the current inputs (i.e., for the task just executed) be saved before proceeding, if you have not already done so.

Once a task has been executed, note that the values for work capacity, perspiration and heat storage under Initial Condition on the Characteristics Screen are no longer zero; instead, they are set to reflect the individuals’ current state after completing the task (see Figure 4-1).

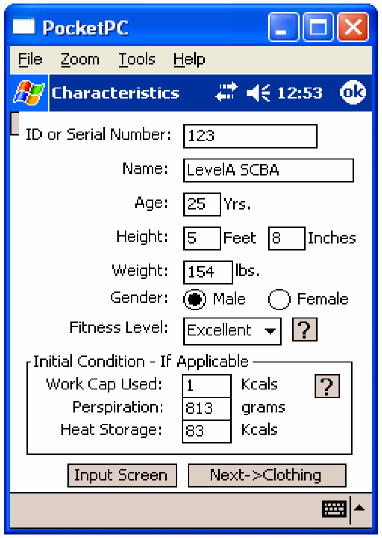

Figure 4-1. Values for Initial Condition after Executing a Task.

The values for Initial Condition can be reset to zero by pressing the Recover Individual button on the Main Input Screen; this action is equivalent to putting the individual at rest (and taking other appropriate measures to "cool off") until he or she has fully recovered to the baseline state before the first task.

A more likely situation is that the user wants to see the outcome should the individual continue immediately with another task. Pressing the Calculate button on the Main Input Screen causes the first task to be executed a second time. The results are cumulative in the case of multiple tasks. Thus, for example, in the case where the first task is repeated, the cumulative heat storage value would be about double that for the first execution of the task.

The second task can be different from the first. For example, you could assign a different activity level or duration, or you could change the environmental conditions (worker characteristics and clothing are unlikely to change). Should you wish to "rest" (but not fully recover) the individual for a period of time before continuing with the next task, simply go to the Activity Screen and select sedentary (or a value up to ~1.2 Met) for the desired time duration. The rest period will not be put into effect until you press the Do Task button. There is no guarantee, however, that "resting" while still wearing PPE will reduce the cumulative heat storage, as other factors such as local environmental conditions come into play.

If you wish to be able to repeat a sequence of tasks at a later time, then be sure to save the inputs for each individual task under a new profile name. You will then be able to load and execute each of the tasks in the same sequence. Note that, if you load the tasks out of sequence or skip one of the tasks, then the results will be misleading because the values saved for Initial Condition are specific to the exact sequence of tasks that you used.

5. EXAMPLE APPLICATIONS

As noted above, you can execute a single task (see Section 5.1) or multiple tasks (Section 5.2).

5.1 Single Task

The inputs for this task can be summarized as follows:

- Characteristics – 25-year-old male, 154 pounds, 5 feet 8 inches tall, in excellent condition
- Clothing – Level A Suit w/open-circuit SCBA (first suit on the list shown in Figure 2-2, clo = 1.02 and I_m = 0.13)
- Activity – Work rate at level 5 Met for 20 minutes
- Environment – Temperature of 88 ºF, relative humidity of 50%, wind speed of 1 mile/hour, full cloud cover

Results for the activity are deemed **Acceptable** (see Figure 5-1).

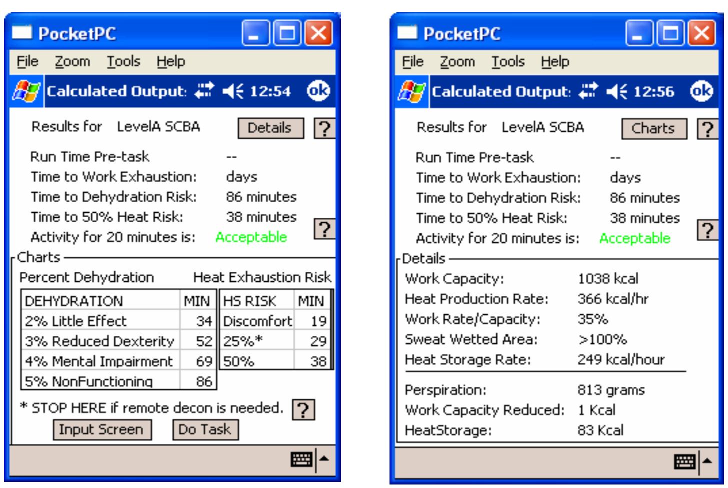

Figure 5-1. Output Screens for First Task.

5.2 Multiple Tasks

For this example, the first task was executed a second time. There are several differences of note in the output (Figure 5-2). First, the Run Time Pre-task (i.e., the cumulative amount of time spent on previous tasks) is now 20 minutes. Second, the activity is now deemed **Unacceptable**, as the 50% heat stress risk level would be reached 19 minutes into the task (i.e., 39 minutes from the start of the first execution of the task).

The 25% heat stress risk level would be reached 9 minutes into this second execution of the task (see the Heat Stress Risk outputs in the lower-right portion of the left-hand screen). As indicated by the asterisk on the output screen that is next to 25% heat risk, if the individual is working in a hazardous environment such that remote decontamination (decon) is required before the PPE can be removed, then the time to 25% heat risk should not be exceeded as the individual could store additional heat en route to decon.

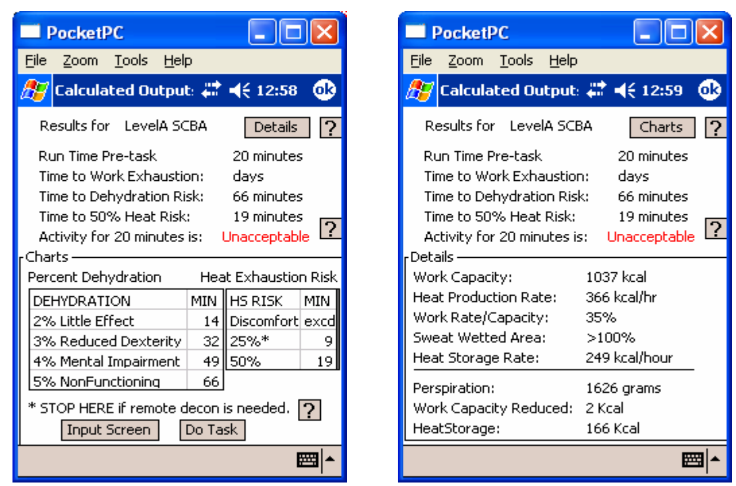

Figure 5-2. Output Screens for Second Task.