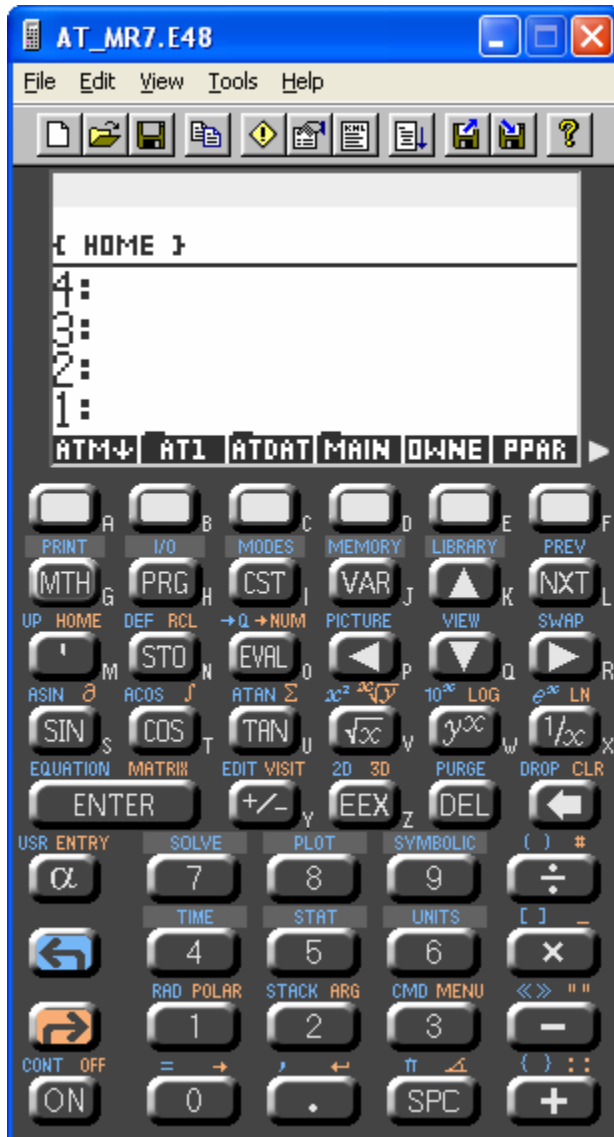


# HP48SX Atmospheric Thermodynamic Calculator Program

User Instructions  
LMM 3 April 2007 - Draft



## Home menu

Note calculator turns off after 5 minutes to save batteries☺  
Press ON to restart

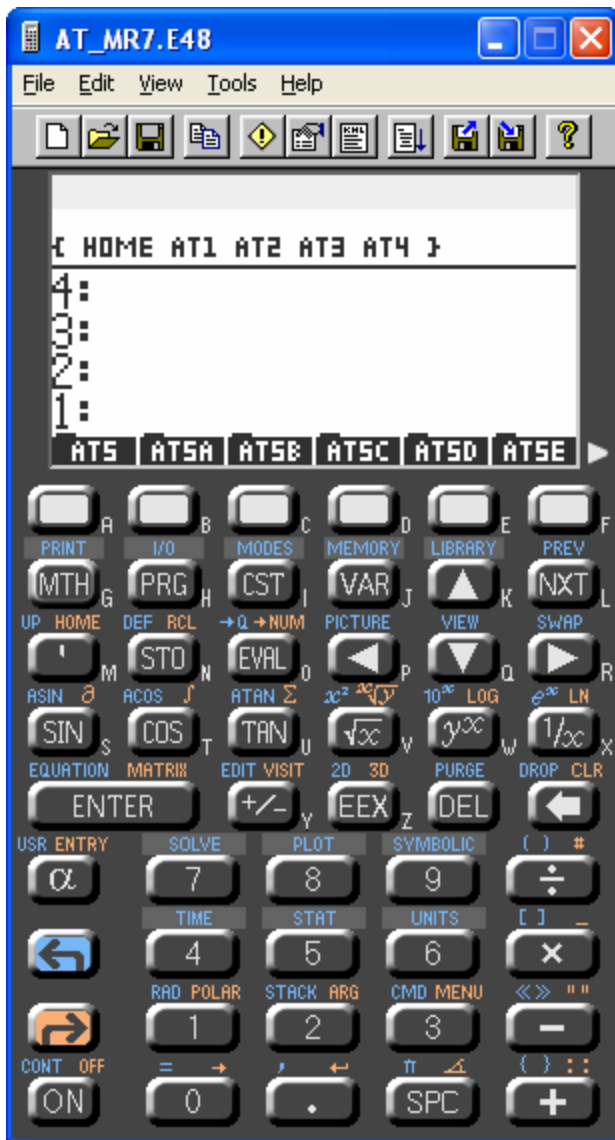
To get to the HOME menu

Press [VAR]

Press [Orange arrow] and [HOME]

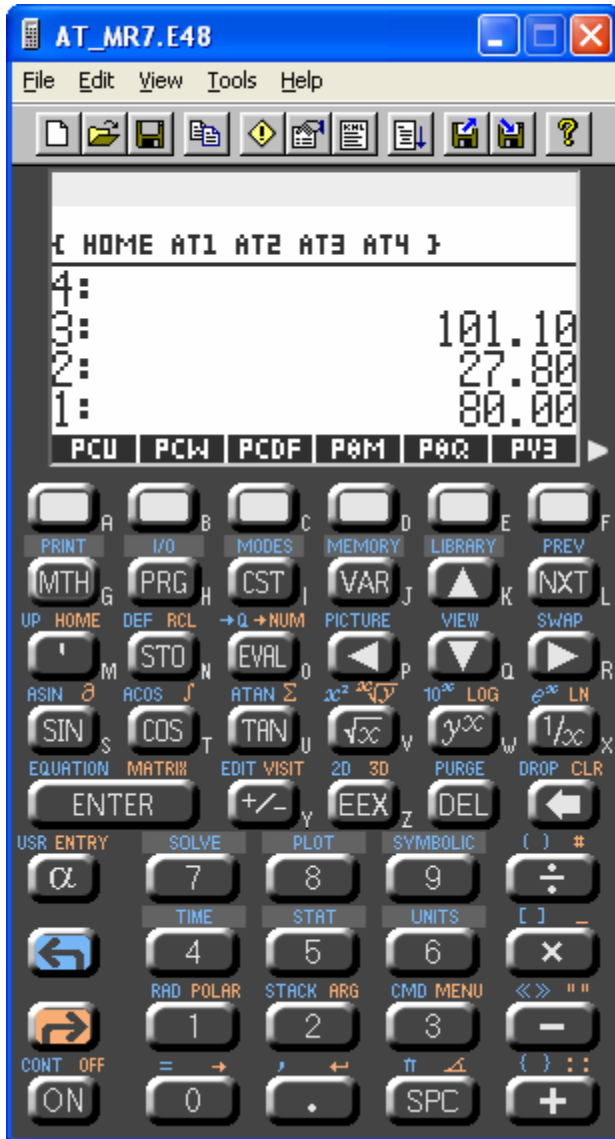
Set Mode to fixed 2 decimal, press [BLUE] [MODES] [2] [FIX]

Press [ATM down arrow] to get to the AT4 directory



Press [NEXT] [NEXT] [NEXT] until you see PCU

Note: For some unexplained reason the orange and blue keys on the emulator are reversed of what they are on the calculator. It does not matter provided the color corresponds to the name next to the key.



### Individual Property Calculations

Try replicating the Isabel intensity calculations from Table 1 below.

Enter ambient air conditions

101.1 [ENTER]

27.8 [ENTER]

80 [ENTER]

Press {PCD}

Results in standard PKM format:

Pressure 101.1

Temperature 300.95

Mixing ratio 19.06

Calculate entropy  
Press [NEXT] until you see ST3, press ST3  
Result 266.79

Calculate enthalpy  
Press [VAR]  
Press [NEXT] until you see {R}  
Press {R} to restore PKM data to the stack  
Press [NEXT] until you see HT3, press HT3  
Result 76572

Other thermodynamic properties can be calculated in the same way – the suffix 3 means calculate from the three standard properties.  
U3 is relative humidity, Rho3 is density, PV3 is water partial pressure, MV3, ML3 and MI3 are the water in vapor, liquid, and ice phase.

### Data Entry Options

The data can be entered in any format and is always converted to PKM format and stored in standard PKM format is stored in variables PP TT and MM.  
PKM is pressure, temperature in K and mixing ratio in g/kg.  
PKU is pressure, temperature in K and relative humidity in percent.  
PCD is pressure, temperature in C, and dewpoint in C.  
PCM is pressure, temperature in C, and mixing ratio in g/kg.  
PCU is pressure, temperature in C and relative humidity in percent.  
PCW is pressure, temperature in C, and wetbulb in C.

You can view a program putting its name on the stack and visiting

To view [PKM]  
Press ['] [PKM] (apostrophe then PKM)  
Press [Orange] [VISIT]  
The program code in RPN (Reverse polish Notation) notation is:  
<<'MM' STO 'TT' STO 'MM' STO' R>>  
Press [ON] to remove the program from the stack without modifying it.

Now View [PCD]  
Low case letters are often used to indicate the variables that are to be supplied by the used.  
-> p c d local variables indicate that the variables that must be supplied before running the program.

Now view [U3]  
This program is written in algebraic notation indicated by the apostrophes and not in RPN because algebraic notation is easier to read. The combination of local variables and algebraic notation make programs easier to understand.

**Table 1.** Hurricane Isabel Maximum Potential Intensity (MPI) calculated with the total energy equation method – (TEE-MPI).

Ambient air properties:  $P_1 = 101.1$  kPa,  $T_1 = 27.8$  °C,  $U_1 = 80$ ,  $r_1 = r_2 = 19.06$  g kg<sup>-1</sup>,  $\mu_1 = h_1 = 76572$  J kg<sup>-1</sup>,  $s_1 = s_2 = 266.8$  J K<sup>-1</sup>kg<sup>-1</sup>.

Temperature approach A = 2 °C, Humidity approach B = 3%,  $U_3 = 100 - B = 97\%$ .

SST (°C)	<b>26.0</b>	<b>26.5</b>	<b>27.0</b>	<b>27.5</b>
<u>Rising air properties:</u>				
$P_2 = P_3$ (kPa)	<b>99.14</b>	<b>97.72</b>	<b>96.01</b>	<b>94.36</b>
$T_2$ (°C)	26.12	24.90	23.41	22.72
$U_2$ (%)	86.8	92.2	99.3	101.75
$\mu_2 = h_2$ (J kg <sup>-1</sup> )	74830	73557	72005	70490
$T_3$ (°C)	<b>24</b>	<b>24.5</b>	<b>25.0</b>	<b>25.5</b>
$U_3$ (%)	<b>97</b>	<b>97</b>	<b>97</b>	<b>97</b>
$r_3 = r_4$ (g kg <sup>-1</sup> )	18.69	19.57	20.55	21.57
$h_3 = \mu_3 = \mu_4$ (J kg <sup>-1</sup> )	71686	74434	77459	80590
$s_3 = s_4$ (J K <sup>-1</sup> kg <sup>-1</sup> )	256.2	269.7	285.2	300.8
$P_4$ (kPa)	15.0	10.0	10.0	10.0
$T_4$ (°C)	-61.45	-80.92	-77.72	-74.42
$T_{4V}$ (°C)	-65.32	-84.69	-81.65	-78.61
$T_{4A}$ (°C)	-62.9	-80.1	-80.1	-80.1
$z_4$ (m)	14220	16570	16570	16570
$h_4$ (J kg <sup>-1</sup> )	-70275	-91130	-88264	-85299
<b>Base Pressure Reduction (kPa)</b>				
$\Delta P_{12}$	<b>1.96</b>	<b>3.38</b>	<b>5.09</b>	<b>6.74</b>
$\Delta P_2$	n/a	base	1.71	3.36
<b>Work (J kg<sup>-1</sup>)</b>				
$W = h_1 - h_2$	<b>1742</b>	<b>3015</b>	<b>4567</b>	<b>6081</b>
$\Delta W$	n/a	base	1552	3066
<b>Velocity (m s<sup>-1</sup>)</b>				
$v = (2W)^{0.5}$	<b>59.0</b>	<b>77.6</b>	<b>95.6</b>	<b>110.3</b>
$\Delta v$ (%)	n/a	base	18.0	32.7
<b>Sensitivity</b>				
$\Delta P_3 / \Delta T_3 = 3.36$ kPa/K				
$\Delta W / \Delta T_3 = 3076$ J kg <sup>-1</sup> /K				
$\Delta v / \Delta T_3 = 32.7$ m s <sup>-1</sup> /K, versus 2 m s <sup>-1</sup> /K for E-MPI method.				
<b>Heat Supplied (J kg<sup>-1</sup>)</b>				
$Q_{23r}$	-3144	877	5454	10100
$Q_{12i}$	-4886	-2138	887	4018
$\Delta Q_{23r}$	n/a	base	4577	9223
<b>Incremental Efficiency</b>				
$n$ (%) = $\Delta W_{12} / \Delta Q_{23r}$	n/a	base	33.9	33.2
$n$ (%) = $1 - T_4 / T_3$	28.8	35.4	33.5	33.5

### Solver Functions

Calculate temperature after isentropic expansion.

Re-enter ambient air conditions or press R then clear the stack by pressing [Orange] [CLEAR]

Enter 96.01 - the pressure for Case 3 condition 2

Press [NEXT] until you see [TSOL], press [TSOL]

Result 296.56 K

Press [KC] to convert from K to C, Result 23.41 C

Press [DROP]

Press [R] to see state 2 conditions: 96.01, 296.56, 19.06

Press [ST3]. Verify that entropy in state 2 is still 266.79

Press [R]

Press [HT3]. Verify that enthalpy in state 2 is 72006

### Notes:

Press [VAR] to get to the first page of menu

Commands can be entered by typing name rather than searching through the menu.

To recall standard variable press [ALPHA] and [R].

To calculate entropy press [ALPHA] twice and key in ST3.

To toggle between degrees K and C. Press [ALPHA] twice and KC.

KC is in the AT3. To go to level AT3 press [Blue] and [UP].

Many of the commonly used functions are in the custom menu that can be accessed by pressing [CST].

To convert from degrees K to C and vice versa, press [CST] and [F].

To find out how KC works, go up to level 3, find KC, and visit it.

### Complex Calculations

Isabel intensity calculation are in directory AT5J.

Press AT5J which is on page 2 of menu AT4.

See the first page of the AT5J menu below

Enter ambient conditions:

101.1, 27.8, and 80. Press PCM1

Enter SST (sea surface temperature), temperature approach, and relative humidity approach.

27, 2, and 3. press SAB.

Press [NEXT] until you see [P4] and [Z4].

Store 10 in [P4] and 16570 in [Z4].

Note: numbers can be sorted by putting the number on the stack and pressing the blue key followed by user defined key ie [P4].

Press [VAR] to go back to the first page of menu AT5J

Enter a guess for the pressure 95 and press [WA2]

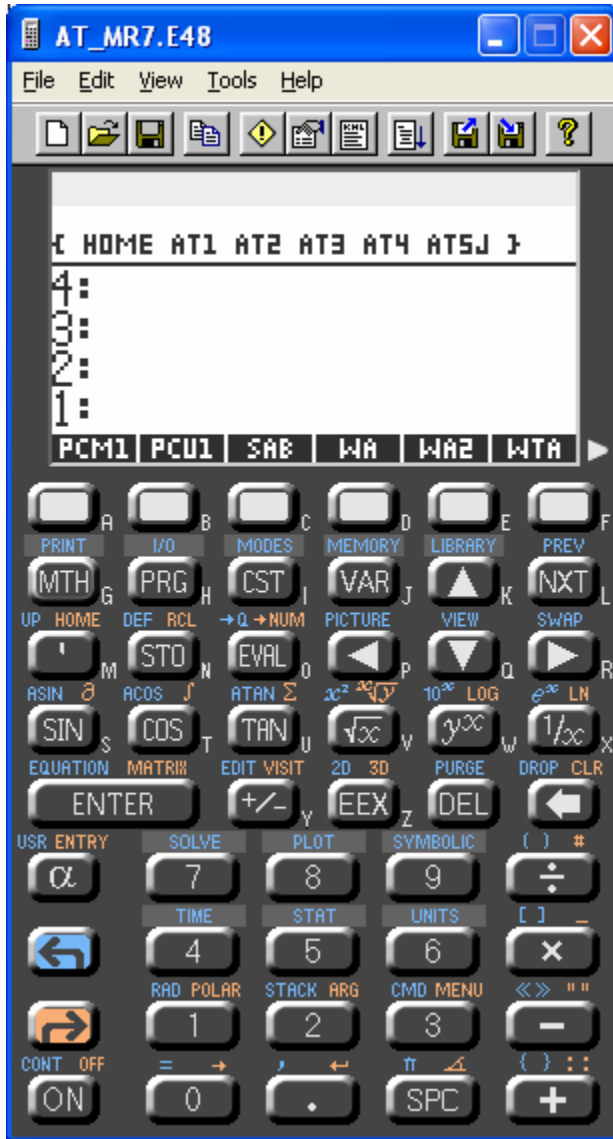
Result 95.98, -12.24.

The second number (-12.4) is the work discrepancy from zero.

Recalculate with a better guess, drop the work discrepancy and press [WA2] again.

Result 96.01 kPa.

Page through the AT5J menu to find Pressure, Temperature, Mixing Ratio, Entropy, Enthalpy at the four states plus energy transfer during changes of state.



Note: You are ready for the Isabel intensity manuscript.

Isabel intensity calculations were done on the real calculator while reading a Bulletin of the American Meteorological Society article with new Isabel data.