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**Software for the IAPWS-IF97
Industrial Formulation
for Water und Steam**

**FluidTI
LibIF97
for the
TI-83 and the TI-83 Plus**

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Software for the IAPWS-IF97 Industrial Formulation for Water and Steam

FluidTI LibIF97 for the TI-83 TI-83 Plus

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For further pocket calculator software see the following link:

www.steamtables-pocket-calculators.com

For steam tables and further property libraries for Excel® and Mathcad® see the following link:

www.international-steam-tables.com

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0. Package Contents

The "FluidTI for the TI-83 and the TI-83 Plus" CD includes the following files:

\TI_Files with the program files

- FLUIDTI.8xp
- FLUIDTI3.8xp
- FLUIDTI4.8xp
- FLUIDTI5.8xp
- FLUIDTI6.8xp

and list files

- E.8xl
- F.8xl
- G.8xl
- H.8xl

FluidTI_TI-83_LibIF97_Docu.pdf - software documentation

In case the package is shipped, a printed copy will be provided.

1. IAPWS-IF97 Functions

Functional Dependence	Function Name in FluidTI	Property or Function	Unit
$p_s = f(t)$	PS(T)	Saturation pressure from temperature	MPa
$t_s = f(p)$	TS(P)	Saturation temperature from pressure	°C
$v = f(p,t,x)$	V(P,T,X)	Specific volume	m ³ /kg
$h = f(p,t,x)$	H(P,T,X)	Specific enthalpy	kJ/kg
$s = f(p,t,x)$	S(P,T,X)	Specific entropy	kJ/(kg K)
$t = f(p,h)$	T(P,H)	Backward function: temperature from pressure and enthalpy	°C
$t = f(p,s)$	T(P,S)	Backward function: temperature from pressure and entropy	°C
$x = f(p,h)$	X(P,H)	Backward function: vapor fraction from pressure and enthalpy	kg/kg
$x = f(p,s)$	X(P,S)	Backward function: vapor fraction from pressure and entropy	kg/kg

Units:
 t in °C
 p in MPa
 x in (kg saturated steam)/(kg wet steam)

Range of validity: IAPWS-IF97 regions 1 and 2, including wet steam

Liquid region 1: $p = p_s(t)$...100 MPa for 0 °C... 350 °C

Steam region 2: 0.000611 MPa... $p = p_s(t)$ for 0 °C... 350 °C

0.000611 MPa... $p_{23}(t) = p(s = 5.2 \text{ kJ/(kg K)})$ for 350 °C... 590 °C

0.000611 MPa... 100 MPa for 590 °C... 800 °C

Comment on the vapor fraction x and calculations for wet steam

The subprograms automatically deal with the wet steam region. For this purpose the following specifications for the vapor fraction x are to be regarded:

Should the point of state to be calculated lie in the single-phase regions (of liquid or superheated vapor) enter -1 as a value of x . Pressure p and temperature t are given.

Should the point of state to be calculated lie in the wet steam region the value for x to be entered ranges from 0 to 1 (0 = saturated liquid, 1 = saturated vapor).

When calculating wet steam it is adequate to enter either the given value for t and $p = -1$, or the given value for p and $t = -1$, as well as the value for x that ranges from 0 to 1.

If you enter p and t and x when calculating wet steam, the program considers p and t to meet the vapor-pressure curve. Should this not apply an error message is displayed for the selected function to be calculated.

IAPWS-IF97 vapor-pressure curve: $t = 0 \text{ °C} \dots 350 \text{ °C}$

$p = 0.000611 \text{ MPa} \dots p_s(t = 350 \text{ °C}) = 16.5292 \text{ MPa}$

Please note.

Should the calculation result in -1 values have been entered beyond the IAPWS-IF97 scope respectively do not define a point of state. In this case, an error message is displayed.

2. Range of Validity and the FluidTI Program Structure

The International Association for the Properties of Water and Steam IAPWS declared the new IAPWS-IF97 Industrial Formulation for thermodynamic properties of water and steam, referred to as the IF97, internationally binding in September 1997 [1], [2], [3]. That is, this new standard finds worldwide application in final inspection and warranty invoices for plants that use the working fluid water or steam. The IAPWS-IF97 Formulation replaces the former Industrial Formulation IFC-67 [12].

Figure 1 displays the range of validity of the new Industrial Formulation's equation theorem, fully named

"IAPWS Industrial Formulation 1997 for the Thermodynamic Properties
of Water and Steam",

abbreviated

"IAPWS Industrial Formulation 1997" .

The IAPWS-IF97 range of state includes temperatures from 0 °C up to 800 °C at pressures from 0.000611 up to 100 MPa and temperatures up to 2000 °C at pressures up to 10 MPa.

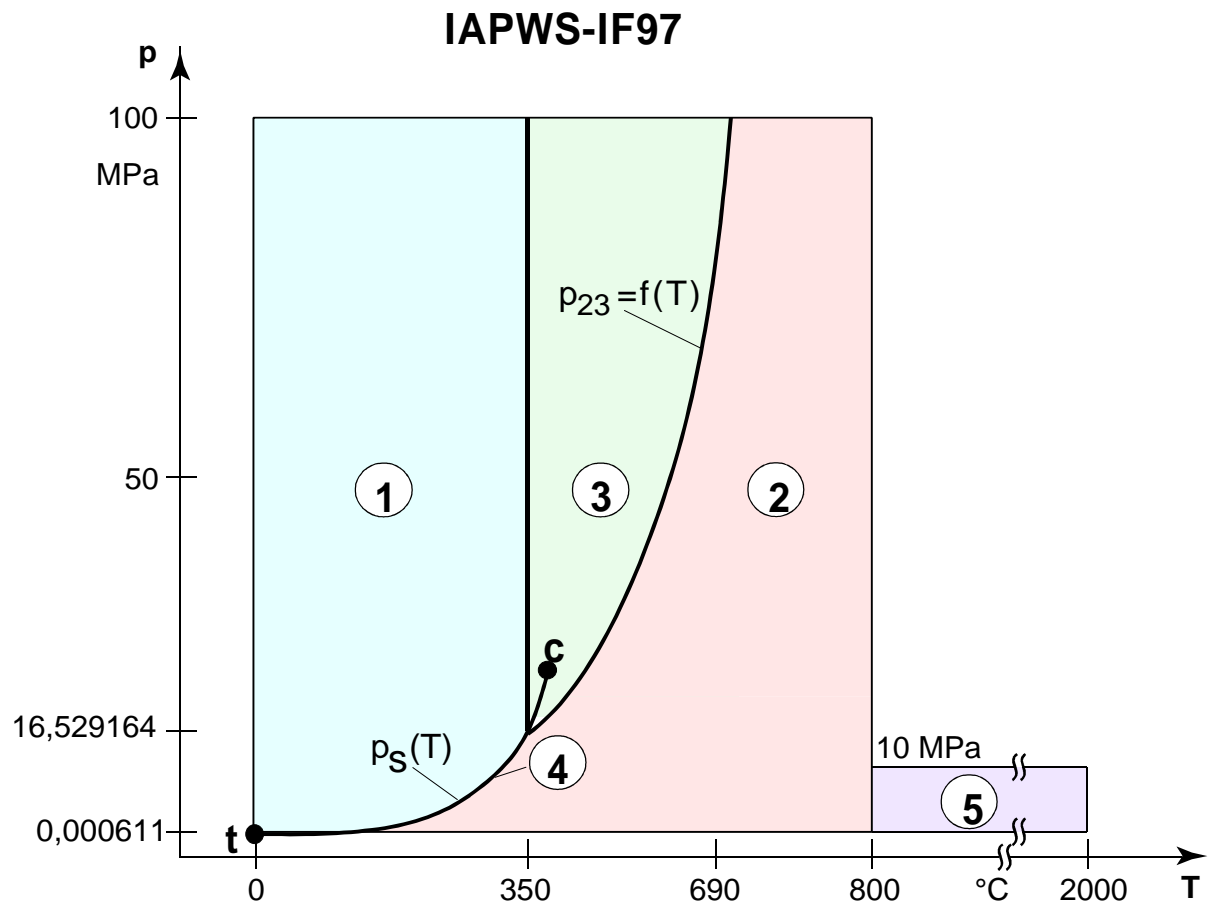


Figure 1: Entire IAPWS-IF97 range of validity

Internally, the entire range of validity is subdivided into five calculation regions in which the appropriate constitutive equations apply (cf. Fig. 1). Those are described in detail in the official IAPWS [1] release and in the publications by *Wagner et al.* [2] and [3].

The FluidTI version at hand is valid for the regions 1, 2, and the wet steam region (region 4) up to a pressure of 16.529164 MPa (cf. Figure 1). Their connection to the calculation equations is established according to the given quantities.

3. Application of FluidTI for the calculation of water and steam

3.1 Installing FluidTI on the TI-83 and the TI-83 Plus

In order to run the FluidTI software on your pocket calculator, load the program from your computer into the calculator, using a special link program and the appropriate link cable.

15 KB of free memory capacity (RAM) are required to load the software into the TI. For the TI-83, free memory can be made available deleting other programs, lists, etc. For the TI-83 Plus, programs can be saved in an ARC-memory without necessarily deleting them. For further information see " Details: The TI-83 Plus flash memory" at the end of chapter 3.1.

The link program is available at service partners of Texas Instruments®, as well as the link cable, or to be downloaded from the TI web site: <http://www.ti.com/calc/docs/link.htm>.

The following description is valid for the

TI-Graph Link 83 Plus

link program which is to be installed first.

This program can be used for the TI-83, too.

(For another link program used for file transfer see the corresponding user's guide or online help.)

Installing FluidTI:

The description is valid for both calculators - the TI-83 and the TI-83 Plus.

1. Connect the TI calculator with the PC as follows.

Plug the link cable in a free PC serial interface (COM1 or COM2) and in the TI calculator.

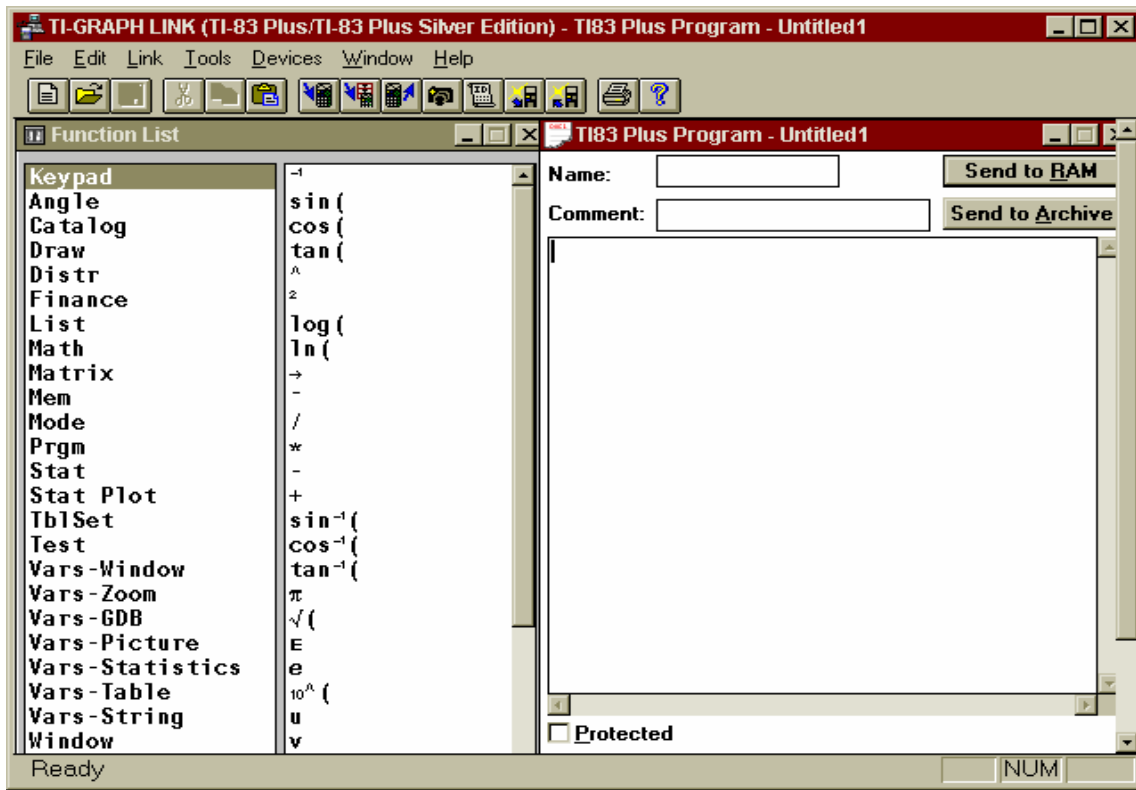
2. Switch on the TI-83 calculator. [The TI-83 Plus switches on automatically as soon as the cable has been plugged in.]

3. Insert the "FluidTI for the TI-83 and the TI-83 Plus" CD into the drive of the PC.

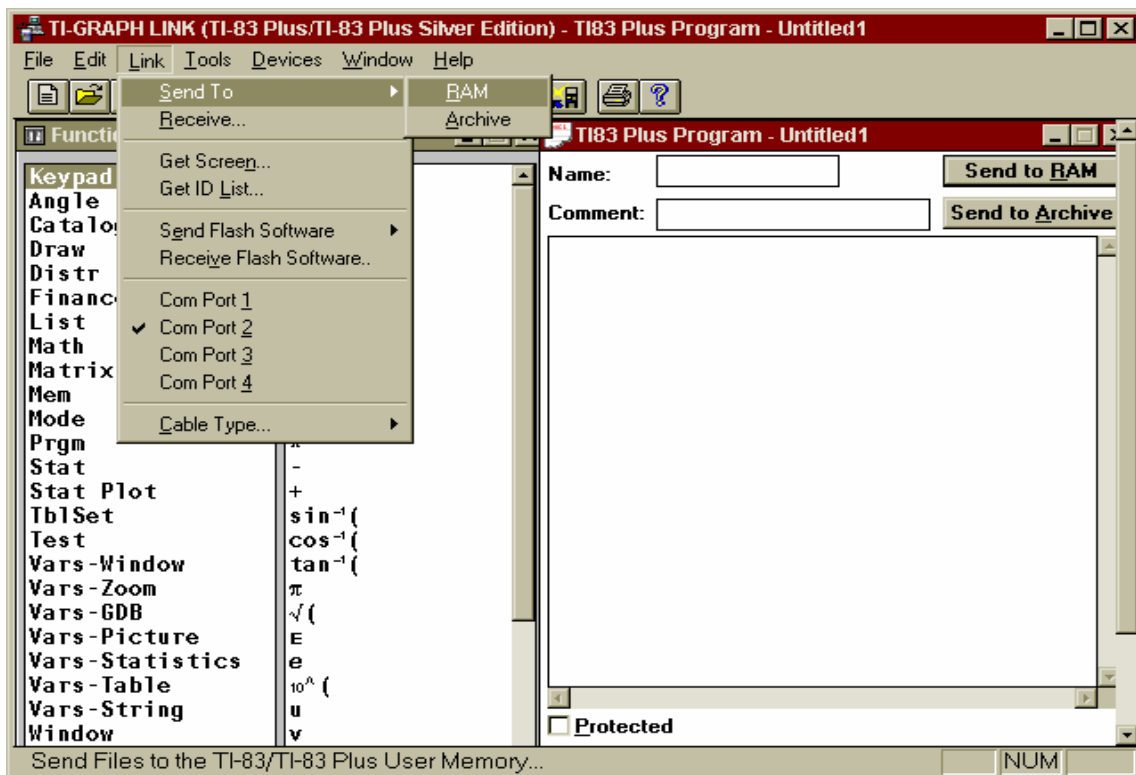
4. Start the TI-Graph Link 83 Plus program on the PC as follows:

In the Windows task bar, click "Start", "Programs", "TI-Graph Link", and "TI-Graph Link 83 Plus".

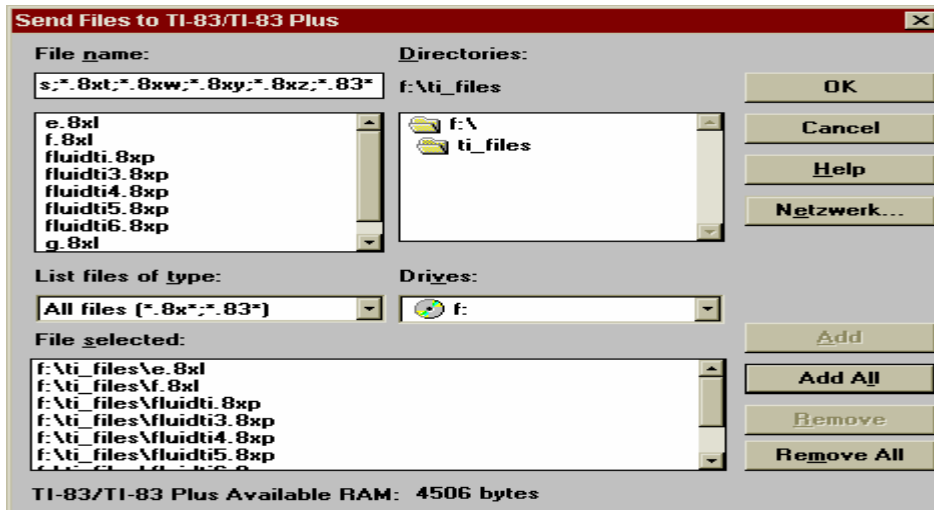
The following window is displayed:



5. In the "Link" pull-down menu, click "Send To", and here "RAM".



6. The "Send Files to TI-83/TI-83 Plus" window is displayed. Should the PC display an error message, see paragraph 8 for help.

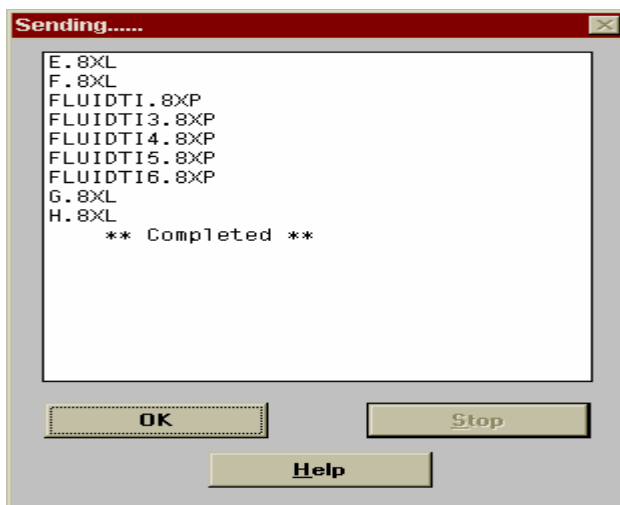


Choose your CD drive in the "Drives" list. With a double click, choose "TI-Files" under "Directories". All TI-files are displayed under "File name:".

7. In the "Send Files to TI-83/TI-83 Plus" window, click the "Add All" button. All files are displayed under "File selected".
8. Click "OK" to start the transfer.

All files selected are loaded into the pocket calculator. The transfer procedure takes a few minutes.

After the transfer is completed, confirm the following window clicking "OK".



Should the files have not been copied to the pocket calculator the transfer failed due to one of the following errors:

- The TI has not been switched on or connected to the computer when the link program was started.
- An inappropriate communication port has been selected (COM 1 ... COM 2 in the "Link" menu).
- An inappropriate link cable has been used or selected in the "Cable type" menu.
- The link cable has not been plugged in properly.

Details: The TI-83 Plus flash memory

In order to achieve more free RAM memory capacity on your TI-83 Plus by saving programs, do as follows:

Enter the memory menu pressing <2nd>, and <MEM> (above the <+> key). The following screen is displayed:

```

MEMO
1:About
2:Mem Mgmt/Del...
3:Clear Entries
4:ClrAllLists
5:Archive
6:UnArchive
7↓Reset...

```

1. Choose "2: Mem Mgmt/Del..." with the cursor block and confirm with <ENTER>, or press <2>. The following window is displayed:

```

RAM FREE    5805
ARC FREE    34997
1:All...
2:Real...
3:Complex...
4>List...
5:Matrix...
6↓Y-Vars...

```

2. If the figure behind "RAM FREE" is higher than 15000, there is enough RAM memory available for the installation of FluidTI. Press <2nd> and <QUIT> (above the <MODE> key) to return.

If there is less than 15 KB memory capacity available, see the next paragraphs.

3. Choose "7: Prgm..." and confirm with <ENTER>, or press <7>.
4. Now, all programs are listed with their memory capacity in Bytes (on the right-hand side). In the "RAM FREE" line, the RAM memory capacity available is displayed. In the "ARC FREE" line, the free archive memory is displayed. Place the cursor with the help of the cursor block in front of a program and press <ENTER> to archive it. Now, a star appears in front of the program. (Should the "Garbage Collect?" window opens instead, see paragraph 7 first.) The star symbolizes the archived state. The figure in the line of "RAM FREE" rises about the size of the archived program. Repeat the procedure until 15 KB RAM memory are available.
5. In order to un-archive a program, place the cursor in front of it and press <ENTER>. The star disappears and the program is back in the RAM memory. After you archived and un-archived programs, the following window is displayed:

```

Garbage Collect?
1:No
2:Yes

```

6. Choose "2: YES" with the cursor block and confirm with <ENTER>, or press <2>. The procedure takes about half a minute. The pocket calculator deletes unnecessary data in the archives.

3.2 Example: Calculate $h = f(p, t, x)$

For the Industrial Formulation IAPWS-IF97 [1, 2, 3], the specific enthalpy h is to be calculated as a function of pressure p , temperature t , and vapor fraction x .

Do as follows:

- Press the <PRGM> key to open the program menu.
- Start the program choosing "FLUIDTI" with the help of the cursor block and press <ENTER> to confirm. "prgmFLUIDTI" is displayed on your calculator screen.

```
Pr-gmFLUIDTI
```

Press <ENTER>.

- The following screen is displayed:

```
FLUIDTI
STEAMTABLES
IAPWS-IF97
VERSION FOR
STUDENTS
```

Details on the TI-83 Plus:

Should the following message be displayed the TI could not find the FLUIDTI program.

```
ERR:ARCHIVED
1:Quit
2:Goto
```

Press <ENTER> and un-archive the FLUIDTI file. In order to do so, see the information under "Details: The TI-83 Plus flash memory" at the end of chapter 3.1 .

Then, start the example again.

- Press <ENTER> for the FluidTI function menu:

```
IAPWS-IF97
1:P(T)
2:TS(P)
3:V(P,T,X)
4:H(P,T,X)
5:S(P,T,X)
6:CONTINUE
7:END
```

- Move the cursor to "6:CONTINUE" and confirm with <ENTER>, or press <6> for further functions:

```

IAPWS-IF97
1: T(P,S)
2: T(P,H)
3: X(P,S)
4: X(P,H)
5: HLP INPUT OF X
6: ABOUT FLUIDTI
7: MENU BEGIN

```

Select "4:MENU BEGIN" with the cursor and confirm with <ENTER>, or press <4> to return to the first part of the menu.

- In the first menu part, select "4:H(P,T,X)" with the cursor block and confirm with <ENTER>, or press <4> to choose the function "h(p,t,x)".

The following input window for pressure p in MPa is displayed:

```

P IN MPa =          .1
P=■ -2->TAKE THIS

```

Consider the IAPWS-IF97 range of validity:

$$p = 0.000611 \text{ MPa} \dots 100 \text{ MPa}$$

→ E.g.: Enter the value 10 and confirm with <ENTER>.

Note: In order to confirm the value displayed in the second line enter -2.

- The input window for the temperature t in °C is displayed:

```

T IN °C =          100
T=■ -2->TAKE THIS

```

Consider the IAPWS-IF97 range of validity:

$$t = 0 \text{ °C} \dots 350 \text{ °C}$$

→ E.g.: Enter the value 400 and confirm with <ENTER>.

- The input window for the vapor fraction x in (kg saturated steam)/(kg wet steam) is displayed:

```

X IN KG/KG =          -1
X=■ -2->TAKE THIS

```

Since the wet steam region is calculated automatically the following details on the vapor fraction x are to be regarded:

Should the point of state to be calculated lie in the single-phase regions (of liquid or superheated vapor) enter the value -1 for x . Pressure p and temperature t are given.

Should the point of state to be calculated lie in the wet steam region the value to be entered for x ranges between 0 and 1 (0 = saturated liquid, 1 = saturated vapor).

When calculating wet steam it is adequate to enter either the value given for t and $p = -1$, **or** the given value for p and $t = -1$, as well as the value for x between 0 and 1. If p and t and x are entered, the program considers p and t to represent the vapor-pressure curve. Should this not be the case an error message is displayed ("OUT OF RANGE").

Wet steam region: $t = 0\text{ °C} \dots 350\text{ °C}$

$p = 0.000611\text{ MPa} \dots 16.5292\text{ MPa}$

→ E.g.: The point of state to be calculated lies in the single-phase region. Therefore, enter the value -1 for x . The program displays the value -1 which you can confirm entering -2.

E.g., enter -2 (Note: Press the <(-)> key before the <2>).

- During the calculation, the following window is displayed:

```
TI IS WORKING
```

Details on the TI-83 Plus

Should the following message be displayed the TI could not find all files.

```
ERR:ARCHIVED
1:Quit
2:Goto
```

Press <ENTER> and un-archive the FLUIDTI3, FLUIDTI4, FLUIDTI5, FLUIDTI6 files and the "E", "F", "G" and "H" lists. In order to do so, see the information under "Details: The TI-83 Plus flash memory" at the end of chapter 3.1 .

Then, start the example again.

- After the calculation, the result for h in kJ/kg is displayed:

```
STEAM REGION
H IN KJ/KG =
    3097.375274
```

→ In the example, the calculation results in 3097.375274.

The calculation of $h = f(p,t,x)$ is complete.

Note: The value calculated for h has been saved as the variable "Θ" (<Θ> key).

Further on, that variable can be used independently of FluidTI.

With the next calculation, FluidTI overwrites the variable "Θ".

The values of v, s, t, and x would be saved as well after they have been calculated.

Now, press <ENTER> to return to the main menu.

Choose "7:END" with the help of the cursor block and confirm with <ENTER>, or press <7> to finish the FluidTI program.

3.3 Uninstalling FluidTI from the TI-83

Do as follows:

1. Enter the memory menu pressing <2nd> and <MEM> (above the <+> key). The following screen is displayed:

```

MEMORY
1:Check RAM...
2:Delete...
3:Clear Entries
4:ClrAllLists
5:Reset...

```

2. Choose "2:Delete..." with the cursor block and confirm with <ENTER>, or <2>. The following window is displayed:

```

DELETE FROM
1:All...
2:Real...
3:Complex...
4:List...
5:Matrix...
6:V-Vars...
7↓Prgm...

```

3. Choose "7:Prgm..." and confirm with <ENTER>, or press <7> for the "Delete: Prgm" menu. The following window is displayed:

```

DELETE:Prgm
▶FLUIDTI      6510
FLUIDTI3     119
FLUIDTI4     1395
FLUIDTI5     2536
FLUIDTI6     142

```

4. Search the "FLUIDTI" file. Press <ENTER> to delete this file.
5. Repeat the erasing procedure for the following files: "FLUIDTI3", "FLUIDTI4", "FLUIDTI5", and "FLUIDTI6".

6. Repeat the instructions of both paragraph 1 and 2. The following window is displayed:

```

DELETE FROM...
1: All...
2: Real...
3: Complex...
4: List...
5: Matrix...
6: V-Vars...
7↓Prgm...

```

7. Choose "4: List..." and confirm with <ENTER>, or press <4> for the "Delete: List" menu. The following window is displayed:

```

DELETE: List
▶E      846
F      999
G      846
H      891

```

8. Go to the "E" list. Press <ENTER> to delete that list.
 9. Repeat the erasing procedure for the following lists: "F", "G", and "H".
 10. Press <2nd>, and <QUIT> (above the <MODE> key) to return.

FluidTI has been uninstalled.

3.4 Uninstalling FluidTI from the TI-83 Plus

Do as follows:

1. Enter the memory menu pressing <2nd>, and <MEM> (above the <+> key). The following screen is displayed:

```

1:About
2:Mem Mgmt/Del...
3:Clear Entries
4:ClrAllLists
5:Archive
6:UnArchive
7↓Reset...

```

2. Choose "2:Mem Mgmt/Del..." with the help of the cursor block and confirm with <ENTER>, or press <2>. The following window is displayed:

```

RAM FREE      8896
ARC FREE      36358
1:All...
2:Real...
3:Complex...
4>List...
5:Matrix...
6↓Y-Vars...

```

3. Choose "7: Prgm..." and confirm with <ENTER>, or press <7> for the "Delete: Prgm" menu. The following window is displayed:

```

RAM FREE      8896
ARC FREE      36358
FLUIDTI       65138
FLUIDTI3      12122
FLUIDTI4      13398
FLUIDTI5      25399
FLUIDTI6      145

```

4. Search the "FLUIDTI" file. Now press the key.

```

Are You Sure?
1:No
2:Yes

```

Choose "2:YES" with the cursor block and confirm with <ENTER>, or press <2>.

5. Repeat the erasing procedure for the following files: "FLUIDTI3", "FLUIDTI4", "FLUIDTI5", and "FLUIDTI6".

6. Repeat the instructions under both paragraph 1 and 2. The following window is displayed:

```

RAM FREE      8896
ARC FREE     36358
1: All...
2: Real...
3: Complex...
4: List...
5: Matrix...
6: V-Vars...

```

7. Choose "4: List..." and confirm with <ENTER>, or press <4> for the "Delete: List" menu. The following window is displayed:

```

RAM FREE      8896
ARC FREE     36358
*
1: All...
2: Real...
3: Complex...
4: List...
5: Matrix...
6: V-Vars...

```

8. Search the "E" list. Then, press the key.

```

Are You Sure?
1: No
2: Yes

```

Choose "2: YES" with the cursor block and confirm with <ENTER>, or press <2>.

9. Repeat the erasing procedure for the following lists: "F", "G", and "H".

10. Press <2nd>, and <QUIT> (above the <MODE> key) to return.

FluidTI has been uninstalled.

4. Program Documentation

Saturation Pressure $p_s = f(t)$

Name in FluidTI: PS(T)

Input

T - temperature t in °C

Output

PS - saturation pressure p_s in MPa

Range of validity

From t = 0 °C to t = 373.946 °C .

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

t < 0 °C or t > 373.946 °C

References: [1], [2], [3], [4], [5]

Saturation Temperature $t_s = f(p)$

Name in FluidTI: TS(P)

Input

P - pressure of p in MPa

Output

TS - saturation temperature t_s in °C

Range of validity

From $p = 0.000611$ MPa to $p = 22.064$ MPa .

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

$p < 0.000611$ MPa or $p > 22.064$ MPa

References: [1], [2], [3], [4], [5]

Specific Volume $v = f(p,t,x)$

Name in FluidTI: V(P,T,X)

Input

P - pressure p in MPa

T - temperature t in °C

X - vapor fraction x in (kg saturated steam)/(kg wet steam)

Output

V - specific volume v in m³/kg

Range of validity

Liquid region : $p = p_s(t)$... 100 MPa at 0 °C... 350 °C

Steam region : 0.000611 MPa... $p = p_s(t)$ at 0 °C... 350 °C

0.000611 MPa... $p_{23}(t) \approx p(s = 5.2 \text{ kJ/(kg K)})$ at 350 °C... 590 °C

0.000611 MPa... 100 MPa at 590 °C... 800 °C

Comment on the vapor fraction x and calculations for wet steam

Since the wet steam region is calculated automatically, the following details on the vapor fraction x are to be regarded:

Should the point of state to be calculated lie in the single-phase region (of liquid or superheated vapor) enter the value -1 for x . Pressure p and temperature t are given.

Should the point of state to be calculated lie in the wet steam region the value to be entered for x ranges between 0 and 1 (0 = saturated liquid, 1 = saturated vapor).

When calculating wet steam it is adequate to enter either the value given for t and $p = -1$, or the value given for p and $t = -1$, as well as the value for x between 0 and 1. If p and t and x are entered the program considers p and t to represent the vapor-pressure curve. If this is not the case an error message is displayed.

Wet steam region: $t = 0$ °C ... 350 °C

$p = 0.000611$ MPa ... 16.5292 MPa

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

Single-phase region: The parameters entered lie beyond the above mentioned range of validity. ($x = -1$)

Wet steam region: at $p = -1$ and $t > 350$ °C or $t < 0$ °C or

($0 \leq x \leq 1$) at $t = -1$ and $p > 16.5292$ MPa or $p < 0.000611$ MPa or

at $p > 16.5292$ MPa or $p < 0.000611$ MPa

and $t > 350$ °C or $t < 0$ °C

at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3], [4], [5]

Specific Enthalpy $h = f(p,t,x)$

Name in FluidTI: H(P,T,X)

Input

P - pressure p in MPa

T - temperature t in °C

X - vapor fraction x in (kg saturated steam)/(kg wet steam)

Output

H - specific enthalpy h in kJ/kg

Range of validity

Liquid region : $p = p_s(t)$... 100 MPa at 0 °C... 350 °C

Steam region : 0.000611 MPa... $p = p_s(t)$ at 0 °C... 350 °C

0.000611 MPa... $p_{23}(t) \approx p(s = 5.2 \text{ kJ/(kg K)})$ at 350 °C... 590 °C

0.000611 MPa... 100 MPa at 590 °C... 800 °C

Comment on the vapor fraction x and calculations for wet steam

Since the wet steam region is calculated automatically, the following details on the vapor fraction x are to be regarded:

Should the point of state to be calculated lie in the single-phase region (of liquid or superheated vapor) enter the value -1 for x . Pressure p and temperature t are given.

Should the point of state to be calculated lie in the wet steam region the value to be entered for x ranges between 0 and 1 (0 = saturated liquid, 1 = saturated vapor).

When calculating wet steam it is adequate to enter either the value given for t and $p = -1$, or the value given for p and $t = -1$, as well as the value for x between 0 and 1. If p and t and x are entered the program considers p and t to represent the vapor-pressure curve. If this is not the case an error message is displayed.

Wet steam region: $t = 0$ °C ... 350 °C

$p = 0.000611$ MPa ... 16.5292 MPa

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

Single-phase region: The parameters entered lie beyond the above mentioned range of validity. ($x = -1$)

Wet steam region: at $p = -1$ and $t > 350$ °C or $t < 0$ °C or

($0 \leq x \leq 1$) at $t = -1$ and $p > 16.5292$ MPa or $p < 0.000611$ MPa or

at $p > 16.5292$ MPa or $p < 0.000611$ MPa

and $t > 350$ °C or $t < 0$ °C

at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3], [4], [5]

Specific Entropy $s = f(p,t,x)$

Name in FluidTI: S(P,T,X)

Input

P - pressure p in MPa

T - temperature t in °C

X - vapor fraction x in (kg saturated steam)/(kg wet steam)

Output

S - specific entropy s in kJ/(kg K)

Range of validity

Liquid region : $p = p_s(t)$... 100 MPa at 0 °C... 350 °C

Steam region : 0.000611 MPa... $p = p_s(t)$ at 0 °C... 350 °C

0.000611 MPa... $p_{23}(t) \approx p(s = 5.2 \text{ kJ/(kg K)})$ at 350 °C... 590 °C

0.000611 MPa... 100 MPa at 590 °C... 800 °C

Comment on the vapor fraction x and calculations for wet steam

Since the wet steam region is calculated automatically, the following details on the vapor fraction x are to be regarded:

Should the point of state to be calculated lie in the single-phase region (of liquid or superheated vapor) enter the value -1 for x . Pressure p and temperature t are given.

Should the point of state to be calculated lie in the wet steam region the value to be entered for x ranges between 0 and 1 (0 = saturated liquid, 1 = saturated vapor).

When calculating wet steam it is adequate to enter either the value given for t and $p = -1$, or the value given for p and $t = -1$, as well as the value for x between 0 and 1. If p and t and x are entered the program considers p and t to represent the vapor-pressure curve. If this is not the case an error message is displayed.

Wet steam region: $t = 0$ °C ... 350 °C

$p = 0.000611$ MPa ... 16.5292 MPa

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

Single-phase region: The parameters entered lie beyond the above mentioned range of validity. ($x = -1$)

Wet steam region: at $p = -1$ and $t > 350$ °C or $t < 0$ °C or

($0 \leq x \leq 1$) at $t = -1$ and $p > 16.5292$ MPa or $p < 0.000611$ MPa or

at $p > 16.5292$ MPa or $p < 0.000611$ MPa

and $t > 350$ °C or $t < 0$ °C

at $|t - t_s(p)| > 0.1$ K

References: [1], [2], [3], [4], [5]

Backward Function: Temperature $t = f(p,h)$

Name in FluidTI: T(P,H)

Input

P - pressure p in MPa

H - specific enthalpy h in kJ/kg

Output

T - temperature t in °C

Range of validity

Liquid region: IAPWS-IF97 region 1 (Figure 1)

Steam region: IAPWS-IF97 region 2 (Figure 1)

Wet steam region: $p = 0.000611 \dots 16.5292$ MPa and $h'(p) < h < h''(p)$

Comment on the calculations for wet steam

The wet steam region is calculated automatically. With reference to the given values of p and h , a subroutine calculation decides whether the point of state to be calculated lies in the single-phase region (liquid or steam), or in the wet steam region. The appropriate region of state is then calculated.

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

Liquid region : at values of p and h beyond the IAPWS-IF97 region 1 (Figure 1)

Steam region: at values of p and h beyond the IAPWS-IF97 region 2 (Figure 1)

Wet steam region: at values of $p > 16.5292$ MPa or $p < 0.000611$ MPa or
at values of $h < h'(p)$ or $h > h''(p)$

References: [1], [2], [3], [4], [5]

Backward Function: Temperature $t = f(p,s)$

Name in FluidTI: T(P,S)

Input

P - pressure p in MPa

S - specific entropy s in kJ/(kg K)

Output

T – temperature t in °C

Range of validity

Liquid region: IAPWS-IF97 region 1 (Figure 1)

Steam region: IAPWS-IF97 region 2 (Figure 1)

Wet steam region: $p = 0.000611 \dots 16.5292$ MPa

Comment on the calculations for wet steam

The wet steam region is calculated automatically. With reference to the given values of p and h , a subroutine calculation decides whether the point of state to be calculated lies in the single-phase region (liquid or steam), or in the wet steam region. The appropriate region of state is then calculated.

Response on faulty input values

The error message "Out of Range" is displayed for the following input values:

Liquid region: at values of p and h beyond the IAPWS-IF97 region 1 (Figure 1)

Steam region: at values of p and h beyond the IAPWS-IF97 region 2 (Figure 1), with $s < 5.85$ kJ/(kg K)

Wet steam region: at values of $p > 16.5292$ MPa or $p < 0.000611$ MPa

References: [1], [2], [3], [4], [5]

Backward Function: Vapor fraction $x = f(p,h)$
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Name in FluidTI: X(P,H)

Input

P - pressure p in MPa

H - specific enthalpy h in kJ/kg

Output

X - vapor fraction x in kg/kg

Range of validity

Liquid region: IAPWS-IF97 region 1 (Figure 1)

Steam region: IAPWS-IF97 region 2 (Figure 1)

Wet steam region: $p = 0.000611 \dots 16.5292$ MPa and $h'(p) < h < h''(p)$

Comment on the calculations for wet steam

The wet steam region is calculated automatically. With reference to the given values of p and h, a subroutine calculation decides whether the point of state to be calculated lies in the single-phase region (liquid or steam), or in the wet steam region.

Should the point of state to be calculated lie in the wet steam region the value of x is calculated. Should the point of state to be calculated lie in the single-phase region the calculation results in -1.

Response on faulty input values

Should the point of state to be calculated lie in the single-phase region the result $x(p,h) = -1$ is displayed for the following input values:

$$\text{for } p > 16.5292 \text{ MPa or } s < s'(p) \text{ or } s > s''(p)$$

The error message "Out of Range!" is displayed for the following input values:

$$p < 0.000611 \text{ MPa or } p > 100 \text{ MPa}$$

References: [1], [2], [3], [4], [5]

Backward Function: Vapor fraction $x = f(p,s)$

Name in FluidTI: X(P,S)

Input

P - pressure p in MPa

S - specific entropy s in kJ/(kg K)

Output

X - vapor fraction x in kg/kg

Range of validity

Liquid region: IAPWS-IF97 region 1 (Figure 1)

Steam region: IAPWS-IF97 region 2 (Figure 1)

Wet steam region: $p = 0.000611 \dots 16.5292$ MPa and $s'(p) < s < s''(p)$

Comment on the calculations for wet steam

The wet steam region is calculated automatically. With reference to the given values of p and h, a subroutine calculation decides whether the point of state to be calculated lies in the single-phase region (liquid or steam), or in the wet steam region.

Should the point of state to be calculated lie in the wet steam region the value of x is calculated. Should the point of state to be calculated lie in the single-phase region the calculation results in -1.

Response on faulty input values

Should the point of state to be calculated lie in the single-phase region (liquid or steam) the result $x(p,h) = -1$ is displayed for the following input values:

$$\text{for } p > 16.5292 \text{ MPa or } s < s'(p) \text{ or } s > s''(p)$$

The error message "Out of Range!" is displayed for the following input values:

$$p < 0.000611 \text{ MPa or } p > 100 \text{ MPa}$$

References: [1], [2], [3], [4], [5]

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