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Library for Calculating Operation Characteristics of Heat Exchangers from VDI Heat Atlas

FluidEXL *Graphics*
with **LibHeatEx**
for Excel[®]

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**Library for Calculating
Operation Characteristics of
Heat Exchangers from VDI Heat Atlas**

FluidEXL^{Graphics}
LibHeatEx

Contents

- 0. Package Contents
 - 0.1 Zip-files for 32-bit Windows[®]
 - 0.2 Zip-files for 64-bit Windows[®]
- 1. Property Functions
 - 1.1 Functions
 - 1.2 Range of Validity
- 2. Application of FluidEXL^{Graphics} in Excel[®]
 - 2.1 Installing FluidEXL^{Graphics}
 - 2.2 Registering FluidEXL^{Graphics} as Add-In in Excel[®]
 - 2.3 The FluidEXL^{Graphics} Help System
 - 2.4 Licensing the LibHeatEx Property Library
 - 2.5 Example: Calculation of $\Phi_A = f\left(ITYPE, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, NSPEC\right)$
 - 2.6 Removing FluidEXL^{Graphics}
- 3. Program Documentation
- 4. Diagrams of Dimensionless Temperature Changes
- 5. Property Libraries for Calculating Heat Cycles, Boilers, Turbines, and Refrigerators
- 6. References
- 7. Satisfied Customers

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0. Package Contents

0.1 Zip files for 32-bit Windows®

The following zip files are delivered for your computer running a 32-bit version of Windows®.

English zip file "CD_FluidEXL_Graphics_LibHeatEx_Eng.zip" including the following files:

FluidEXL_Graphics_Eng_Setup.exe	- English installation program for the Add-In FluidEXL <i>Graphics</i> for use in Excel®.
FluidEXL_Graphics_Eng.xla	- English Add-In for FluidEXL <i>Graphics</i>
LibHeatEx.dll	- Dynamic Link Library for use in Windows programs
LibHeatEx.hlp	- Help file for the LibHeatEx property library
FluidEXL_Graphics_LibHeatEx_Docu_Eng.pdf	- User's Guide

German zip file "CD_FluidEXL_Graphics_LibHeatEx.zip" including the following files:

FluidEXL_Graphics_Setup.exe	- German installation program for the Add-In FluidEXL <i>Graphics</i> for application in Excel®.
FluidEXL_Graphics.xla	- German Add-In for FluidEXL <i>Graphics</i>
LibHeatEx.dll	- Dynamic Link Library for use in Windows programs
LibHeatEx.hlp	- Help file for the LibHeatEx property library
FluidEXL_Graphics_LibHeatEx_Docu_Eng.pdf	- User's Guide

0.2 Zip files for 64-bit Windows®

The following zip files are delivered for your computer running a 64-bit version of Windows®.

English zip file "CD_FluidEXL_Graphics_LibHeatEx_x64_Eng.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibHeatEx_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics_Eng.xla	- English FluidEXL <i>Graphics</i> Add-In
FluidEXL_Graphics_Eng_64_Setup.msi	- Self-extracting and self-installing program
LibHeatEx.dll	- Dynamic link library for use in Windows® programs

LibHeatEx_Eng.hlp	- English help file for the LibHeatEx property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL ^{Graphics}

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

German zip file "CD_FluidEXL_Graphics_LibHeatEx_x64.zip" including the following files and folders:

Files:

FluidEXL_Graphics_LibHeatEx_Docu_Eng.pdf	- User's Guide
FluidEXL_Graphics.xla	- German FluidEXL ^{Graphics} Add-In
FluidEXL_Graphics_64_Setup.msi	- Self-extracting and self-installing program
LibHeatEx.dll	- Dynamic link library for use in Windows [®] programs
LibHeatEx.hlp	- German help file for the LibHeatEx property library
Setup.exe	- Self-extracting and self-installing program for FluidEXL ^{Graphics}

Folders:

vcredist_x64	- Folder containing the "Microsoft Visual C++ 2010 x64 Redistributable Pack"
WindowsInstaller3_1	- Folder containing the "Microsoft Windows Installer"

1. Property Functions

1.1 Functions

Functional Dependence	Function Name	Call as Function from LibHeatEx DLL	Function
$\Phi_A = f\left(ITYPE, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, NSPEC\right)$	Phi_HeatEx	PHI_HeatEx(ITYPE, kaCA, CACB, NSPEC)	Dimensionless temperature changes
$\frac{k \cdot A}{\dot{C}_A} = f\left(ITYPE, \Phi_A, \frac{\dot{C}_A}{\dot{C}_B}, NSPEC\right)$	kaCA_HeatEx	kaCA_HeatEx (ITYPE, PHI, CACB, NSPEC)	Number of transfer units
$\frac{\dot{C}_A}{\dot{C}_B} = f\left(ITYPE, \Phi_A, \frac{k \cdot A}{\dot{C}_A}, NSPEC\right)$	CACB_HeatEx	CACB_HeatEx (ITYPE, PHI, kaCA, NSPEC)	Heat capacity rate ratios

Units: All quantities are dimensionless.

Equations:

:

Dimensionless temperature changes

$$\Phi = Phi = \frac{t_{H1} - t_{H2}}{t_{H1} - t_{K1}}$$

$$\Phi_A = \Phi_B \cdot \frac{\dot{C}_B}{\dot{C}_A} \quad \Phi_B = \Phi_A \cdot \frac{\dot{C}_A}{\dot{C}_B}$$

Number of transfer units

$$\frac{k \cdot A}{\dot{C}_A} = \frac{\Delta g_A}{\Delta g_{AB}^m} = \frac{k \cdot A}{\dot{C}_B} \cdot \frac{\dot{C}_B}{\dot{C}_A}$$

$$\frac{k \cdot A}{\dot{C}_B} = \frac{\Delta g_B}{\Delta g_{AB}^m} = \frac{k \cdot A}{\dot{C}_A} \cdot \frac{\dot{C}_A}{\dot{C}_B}$$

Determination:

A – heating surface

c_p – heat capacity

k - heat transfer coefficient

Indexing:

A – flow A

B – flow B

H – heating medium

Ratios of the heat capacity rate

$$\frac{\dot{C}_A}{\dot{C}_B} = \frac{\Delta g_B}{\Delta g_A} \quad \frac{\dot{C}_B}{\dot{C}_A} = \frac{\Delta g_A}{\Delta g_B}$$

K – cooling medium

1 – inlet of A and B

2 – outlet of A and B

$\dot{C}_A$ - heat capacity rate flow A

$$\dot{C}_A = \dot{m}_A \cdot c_{pA}$$

$\dot{m}$ - mass flow

$\dot{C}_B$ - heat capacity rate flow B

$$\dot{C}_B = \dot{m}_B \cdot c_{pB}$$

c_p – isobaric heat capacity

Δt_A - temperature changes flow A

$$\Delta t_A = t_{A1} - t_{A2}$$

Δt_B - temperature changes flow B

$$\Delta t_B = t_{B1} - t_{B2}$$

c_{pA}^m - mean isobaric heat capacity of flow A

$$c_{pA}^m = \frac{h_{A2} - h_{A1}}{t_{A2} - t_{A1}} \quad \text{for } p_A \approx \text{const.}$$

approximation:

$$c_{pA}^m \approx \frac{1}{2} [c_{pA}(t_{A1}) + c_{pA}(t_{A2})]$$

h – specific enthalpy

t – temperature

p – pressure of flow A and flow B

c_{pB}^m - mean isobaric heat capacity of flow B

$$c_{pB}^m = \frac{h_{B2} - h_{B1}}{t_{B2} - t_{B1}} \quad \text{for } p_B \approx \text{const.}$$

approximation:

$$c_{pB}^m \approx \frac{1}{2} [c_{pB}(t_{B1}) + c_{pB}(t_{B2})]$$

1.2 Range of Validity

The LibHeatEx property library has been developed to calculate different heat exchangers, which have been taken from the VDI-Heat Atlas [3].

One of the two streams is referred to as heating medium and the other one as cooling medium. The heating medium transfers thermal energy to the cooling medium.

Thermal losses to the surrounding are neglected, which means that the heat exchanger is calculated adiabatically. The result of the first law of thermodynamics are functional coherences between the dimensionless temperature changes Φ , the number of transfer units $\frac{k \cdot A}{\dot{C}_A}$, which is also referred to as NTU or N , and the ratios of the heat capacity rate

$\frac{\dot{C}_A}{\dot{C}_B}$ or R . The basic functional dependency is $\Phi = \Phi = f\left(\frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}\right)$. In most cases the

equation cannot be solved for the other two variables. These functions are $\frac{k \cdot A}{\dot{C}_A} = f\left(\Phi, \frac{\dot{C}_A}{\dot{C}_B}\right)$

and $\frac{\dot{C}_A}{\dot{C}_B} = f\left(\Phi, \frac{k \cdot A}{\dot{C}_A}\right)$, they therefore have to be calculated iteratively. In order to select the

correct type of the heat exchanger, please use Table 1 of this User's Guide or the help file LibHeatEx.hlp. Each heat exchanger type is assigned to one number, which is specified as the variable I_{TYPE} . This is also the first input parameter for each function in Excel[®].

There are also functions with a variable number of tube rows or passes which is indicated by the parameter N_{SPEC} . N_{SPEC} is also given in Table 1 and in the help file LibHeatEx.hlp.

The functional dependencies of flow A with I_{TYPE} and N_{SPEC} are

$$\begin{aligned}\Phi_A &= f\left(I_{TYPE}, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, N_{SPEC}\right), \\ \frac{k \cdot A}{\dot{C}_A} &= f\left(I_{TYPE}, \Phi_A, \frac{\dot{C}_A}{\dot{C}_B}, N_{SPEC}\right), \text{ and} \\ \frac{\dot{C}_A}{\dot{C}_B} &= f\left(I_{TYPE}, \Phi_A, \frac{k \cdot A}{\dot{C}_A}, N_{SPEC}\right).\end{aligned}$$

The dependencies for flow B are

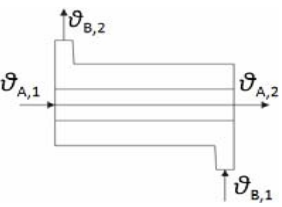
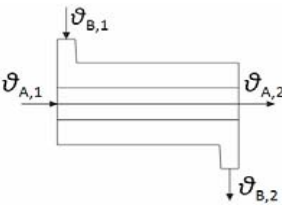
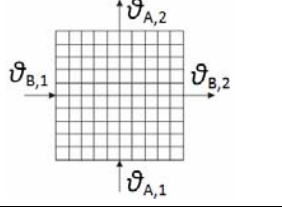
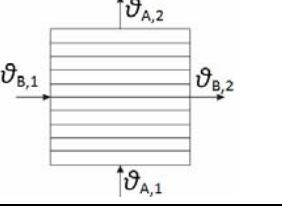
$$\begin{aligned}\Phi_B &= f\left(I_{TYPE}, \frac{k \cdot A}{\dot{C}_B}, \frac{\dot{C}_B}{\dot{C}_A}, N_{SPEC}\right), \\ \frac{k \cdot A}{\dot{C}_B} &= f\left(I_{TYPE}, \Phi_B, \frac{\dot{C}_B}{\dot{C}_A}, N_{SPEC}\right), \text{ and} \\ \frac{\dot{C}_B}{\dot{C}_A} &= f\left(I_{TYPE}, \Phi_B, \frac{k \cdot A}{\dot{C}_B}, N_{SPEC}\right).\end{aligned}$$

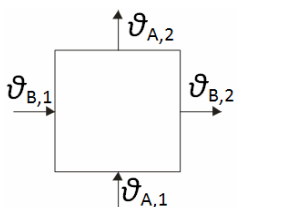
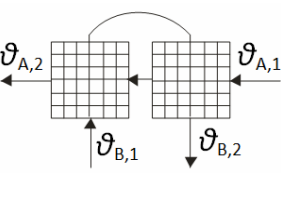
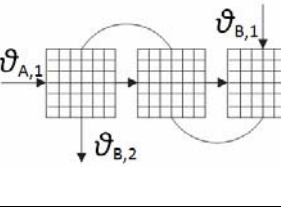
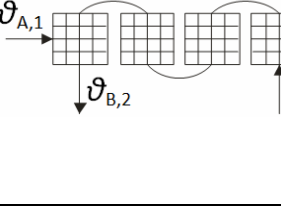
The range of validity for the different parameters are shown in the following Table 1

Table 1: Range of validity

Quantities	Range of validity
Dimensionless temperature changes:	$0 \leq \Phi \leq 1$
Number of transfer units:	$0 < kaCA$
Heat capacity rate ratios:	$0 \leq CACB$
Type of Heat Exchanger:	$0 < ITYPE \leq 24$
Number of tube rows or passes:	$0 = NSPEC$ for $ITYPE$ 1-9; 12-19; 21-24 $0 < NSPEC$ for $ITYPE$ 10; 11; 20

Table 2: List of heat exchanger types

I_{TYPE}	Type	Flow arrangement	N_{SPEC}
1	Pure counter current flow $i = A, B$		0
2	Pure cocurrent flow $i = A, B$		0
3	Pure cross-flow $i = A, B$		0
4	Cross-flow with one tube row, laterally mixed on one side		0

I_{TYPE}	Type	Flow arrangement	N_{SPEC}
5	Cross-flow, laterally mixed on both sides $i = A, B$		0
6	Counterdirected countercurrent cross-flow with two tube rows and two passes		0
7	Counterdirected countercurrent cross-flow with three tube rows and three passes		0
8	Counterdirected countercurrent cross-flow with four tube rows and four passes		0

l_{TYPE}	Type	Flow arrangement	N_{SPEC}
9	Counterdirected countercurrent cross-flow with four tube rows and two passes		0
10	Cross-flow with n tube rows and one pass $n = 1, 2, \dots, \infty$		$1, 2, \dots, \infty$
11	Codirected countercurrent cross-flow with n tube rows and n passes $n = 1, 2, \dots, \infty$		$1, 2, \dots, \infty$
12	Two-sided stirred tank $i = A, B$		0

l_{TYPE}	Type	Flow arrangement	N_{SPEC}
13	One-sided stirred tank		0
14	One shell-side and two tube-side passes $i = A, B$		0
15	One shell-side and three tubeside passes, two countercurrent		0
16	One shell-side and two tubeside passes, both countercurrent		$1, 2, \dots, \infty$

2. Application of FluidEXL^{Graphics} in Excel[®]

The FluidEXL^{Graphics} Add-In has been developed to calculate thermodynamic properties in Excel more conveniently. Within Excel[®], it enables the direct call of functions relating to heat exchangers from the LibHeatEx property library.

2.1 Installing FluidEXL^{Graphics}

If FluidEXL^{Graphics} has not yet been installed or if there is a version installed which has been delivered before June 2010, please complete the initial installation procedure described below.

If FluidEXL^{Graphics} has already been installed in a version which has been delivered after June 2010, you simply need to copy the files which belong to the LibHeatEx library. In this case, follow the subsection "Adding the LibHeatEx Library" on page 2/11.

Installing FluidEXL^{Graphics} for 32-bit Windows[®]

Complete the following steps for initial installation of FluidEXL^{Graphics}.

Before you begin, it is best to uninstall any trial version or full version of FluidEXL^{Graphics} delivered before June 2010.

After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibHeatEx_Eng.zip"	(for English version of Windows)
"CD_FluidEXL_Graphics_LibHeatEx.zip"	(for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibHeatEx_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibHeatEx	(for German version of Windows)

in your Windows Explorer, Norton Commander etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following files:

FluidEXL_Graphics_Eng_Setup.exe	(for English version of Windows)
FluidEXL_Graphics_Setup.exe	(for German version of Windows)
FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
FluidEXL_Graphics_LibHeatEx_Docu_Eng.pdf	
LibHeatEx.dll	
LibHeatEx.hlp	

In order to run the installation of FluidEXL^{Graphics} double-click the file

FluidEXL_Graphics_Eng_Setup.exe	(for English version of Windows)
FluidEXL_Graphics_Setup.exe	(for German version of Windows).

Installation may start with a window noting that all Windows programs should be closed. When this is the case, the installation can be continued. Click the "Continue" button.

In the following dialog box, "Choose Destination Location", the default path offered automatically for the installation of FluidEXL^{Graphics} is

C:\Program Files\FuildEXL_Graphics_Eng	(for English version of Windows)
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C:\Programme\FluidEXL_Graphics (for German version of Windows).

By clicking the "Browse..." button, you can change the installation directory before installation (see figure below).

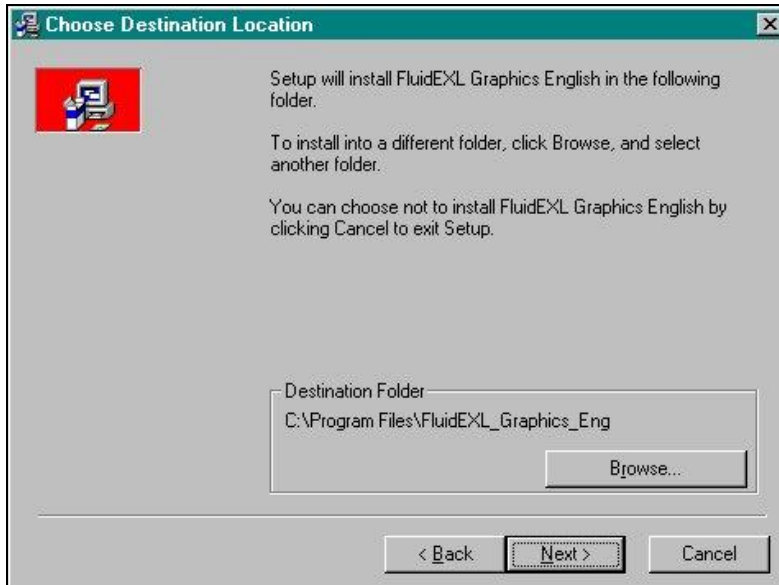


Figure 2.1: Choose Destination Location

Finally, click on "Next" to continue installation; click "Next" again in the "Start Installation" window which follows in order to start the installation of FluidEXL *Graphics*.

After FluidEXL *Graphics* has been installed, the sentence

"FluidEXL Graphics English has been successfully installed."

will be shown. Confirm this by clicking the "Finish" button.

During the installation process the following files

Advapi32.dll	LC.dll
DFORMD.dll	Msvcp60.dll
Dforrt.dll	Msvcrt.dll
UNWISE.EXE	UNWISE.INI
INSTALL_EXL.LOG	

have been copied into the chosen destination folder, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows).

In addition, the two subdirectories \FORMULATION97 and \FLuft have been compiled in the destination folder.

In the next step, the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibHeatEx.dll	
LibHeatEx.hlp	

from the extracted folder

CD_FluidEXL_Graphics_LibHeatEx_Eng	(for English version of Windows)
------------------------------------	----------------------------------

CD_FluidEXL_Graphics_LibHeatEx (for German version of Windows)

must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows),

using an appropriate program such as Explorer or Norton Commander.

Installing FluidEXL *Graphics* for 64-bit Windows®

Complete the following steps for initial installation of FluidEXL *Graphics*.

Before you begin, it is best to uninstall any trial version or full version of FluidEXL *Graphics* delivered before June 2010.

After you have downloaded and extracted the zip-file

"CD_FluidEXL_Graphics_LibHeatEx_x64_Eng.zip" (for English version of Windows)

"CD_FluidEXL_Graphics_LibHeatEx_x64.zip" (for German version of Windows)

you will see the folder

CD_FluidEXL_Graphics_LibHeatEx_Eng (for English version of Windows)

CD_FluidEXL_Graphics_LibHeatEx (for German version of Windows)

in your Windows Explorer, Norton Commander etc.

Now, open this folder by double-clicking on it.

Within this folder you will see the following files

FluidEXL_Graphics_LibHeatEx_Docu_Eng

FluidEXL_Graphics_Eng.xla (for English version of Windows)

FluidEXL_Graphics.xla (for German version of Windows)

FluidEXL_Graphics_Eng_Setup_64.msi (for English version of Windows)

FluidEXL_Graphics_Setup_64.msi (for German version of Windows)

LibHeatEx.dll

LibHeatEx.hlp

Setup.exe

and the folders

vcredist_x64

WindowsInstaller3_1.

In order to run the installation of FluidEXL *Graphics* double-click the file

Setup.exe.

If the "Microsoft Visual C++ 2010 x64 Redistributable Pack" is not running on your computer yet, installation will start with a window noting that the "Visual C++ 2010 runtime library (x64)" will be installed on your machine (see figure below).

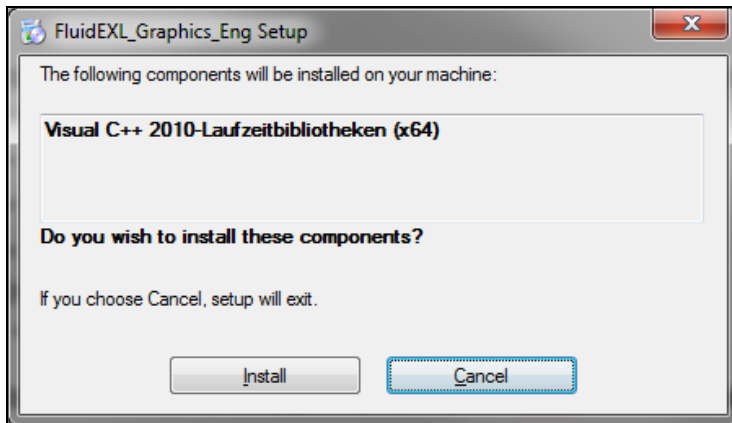


Figure 2.2: Installing the "Visual C++ 2010 runtime library (x64)"

Click on "Install" to continue.

In the following window you are required to accept the Microsoft® license terms to install the "Microsoft Visual C++ 2010 x64 Redistributable Pack" by ticking the box next to "I have read and accept the license terms" (see figure below).

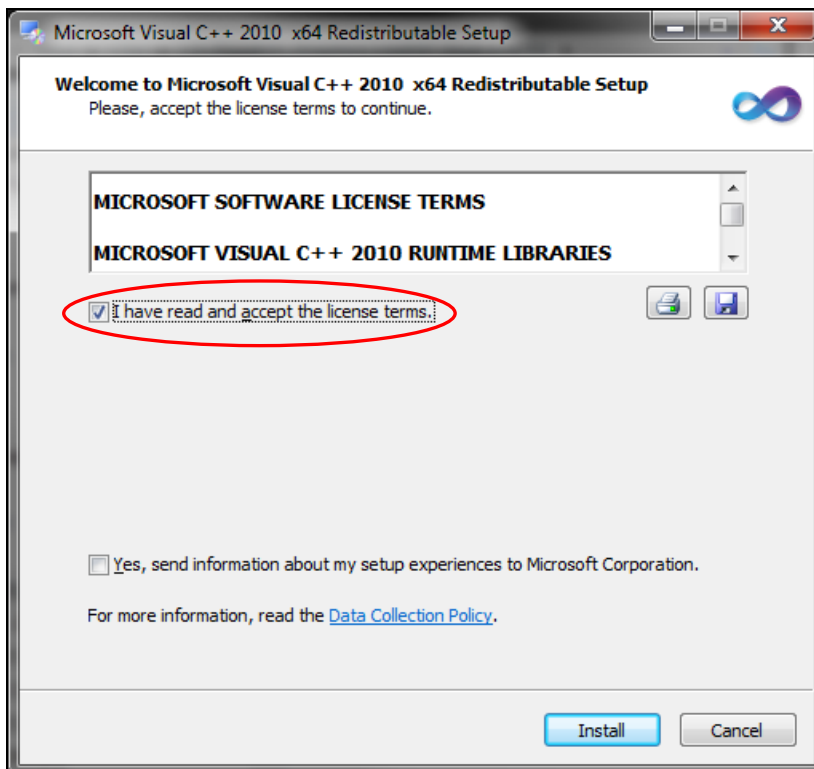


Figure 2.3: Accepting the license terms

Now click on "Install" to continue installation.

After the "Microsoft Visual C++ 2010 x64 Redistributable Pack" has been installed, you will see the sentence "Microsoft Visual C++ 2010 x64 Redistributable has been installed." Confirm this by clicking "Finish."

Now the installation of FluidEXL_Graphics_Eng_64 starts with a window noting that the installer will guide you through the installation. Click the "Next >" button to continue.

In the following dialog box, "Select Installation Folder," the default path offered automatically for the installation of FluidEXL *Graphics* is

C:\Program Files\FuildEXL_Graphics_Eng (for English version of Windows).

C:\Programme\FuildEXL_Graphics (for German version of Windows).

By clicking the "Browse..." button, you can change the installation directory before installation (see Figure 2.4).

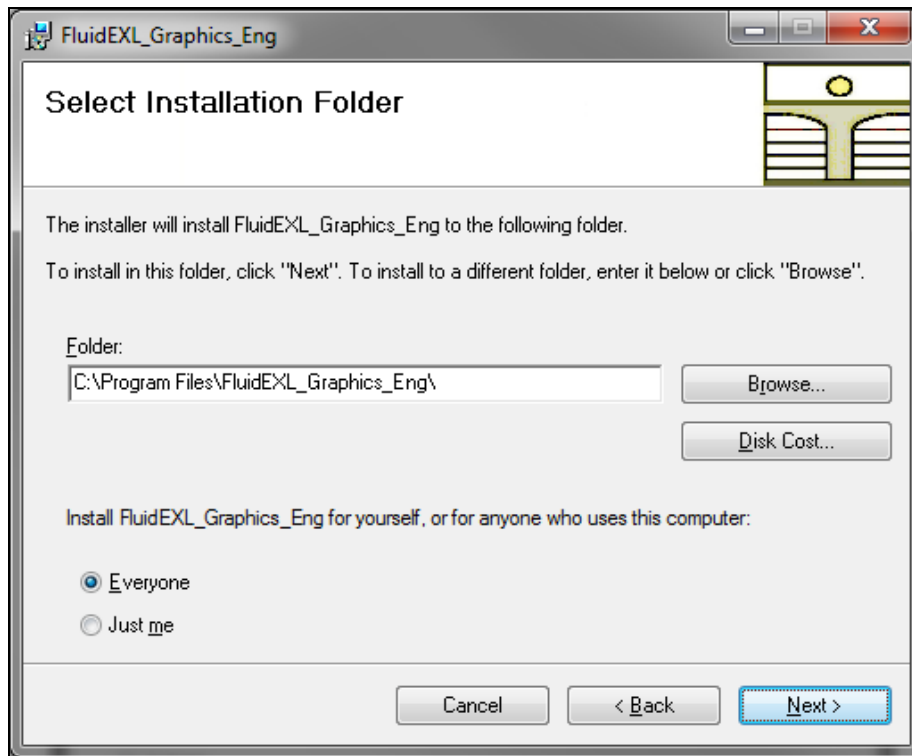


Figure 2.4: Choosing the Installation Folder of FluidEXL *Graphics*

Finally, click on "Next >" to continue installation; click "Next >" again in the "Confirm Installation" window which follows in order to start the installation of FluidEXL *Graphics*.

After FluidEXL *Graphics* has been installed, you will see the sentence "FluidEXL_Graphics_Eng has been successfully installed." Confirm this by clicking the "Close" button.

During the installation process the following files

capt_ico_big.ico	libmmd.dll
libifcoremd.dll	LC.dll
libiomp5md.dll.	

will have been copied into the destination folder chosen, the standard being

C:\Program Files\FuildEXL_Graphics_Eng (for English version)

C:\Programme\FuildEXL_Graphics (for German version).

In addition, the two subdirectories \FORMULATION97 and \FLuft were created in the destination folder.

In the next step, the files below,

FluidEXL_Graphics_Eng.xla (for English version of Windows)

FluidEXL_Graphics.xla (for German version of Windows)
 LibHeatEx.dll
 LibHeatEx.hlp

found in your CD folder, must be copied into the chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 C:\Programme\FluidEXL_Graphics (for German version of Windows))

using an appropriate program such as Explorer or Norton Commander.

2.2 Registering FluidEXL^{Graphics} as Add-In in Excel[®]

Registering FluidEXL^{Graphics} as Add-In in Excel[®], versions 2003 or earlier

After the installation of FluidEXL^{Graphics}, the program must be registered as an Add-In in Excel[®]. In order to do so, start Excel[®] and carry out the following steps:

- Click "Tools" in the upper menu bar of Excel[®].
- Here, click the "Add-Ins..." menu item.
 After a short delay the "Add-Ins" dialog box will appear.
- Click "Browse...."
- In the following dialog box, choose your chosen destination folder (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
 C:\Programme\FluidEXL_Graphics (for German version of Windows))

 here select

"FluidEXL_Graphics_Eng.xla" (for English version of Windows)
 "FluidEXL_Graphics.xla" (for German version of Windows)

 and afterwards click "OK".
- Now, the entry

"FluidEXL Graphics Eng" (for English version of Windows)
 "FluidEXL Graphics" (for German version of Windows)

 will appear in the Add-Ins list.

Note:

As long as the check box next to the file name "FluidEXL Graphics Eng" is checked, this Add-In will be loaded automatically every time you start Excel[®] until you unmark the box by clicking on it again.

In order to register FluidEXL^{Graphics} as an Add-In, click "OK" in the "Add-Ins" dialog box. Now, the new FluidEXL^{Graphics} menu bar will appear in the upper menu area of your Excel[®] screen, marked with a red circle in Figure 2.5.

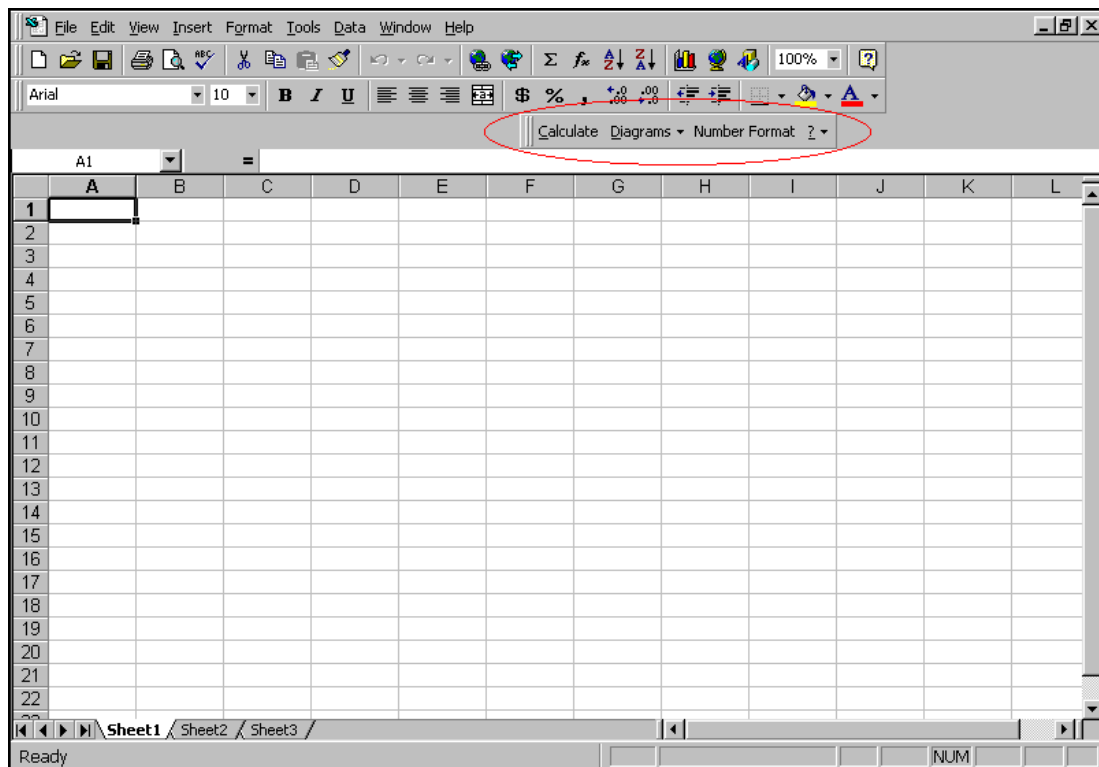


Figure 2.5: Menu bar of FluidEXLGraphics

From within Excel you can now select the "LibHeatEx" DLL library property functions via this menu bar (cf. part 2.5 on page 2/19).

Registering FluidEXL *Graphics* as Add-In in Excel® 2007 (or later versions)

After installation in Windows®, FluidEXL *Graphics* must be registered in Excel® versions 2007 and later as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the Windows Office® button in the upper left hand corner of Excel®
- Click on the "Excel Options" button in the menu which appears (see Figure 2.6)

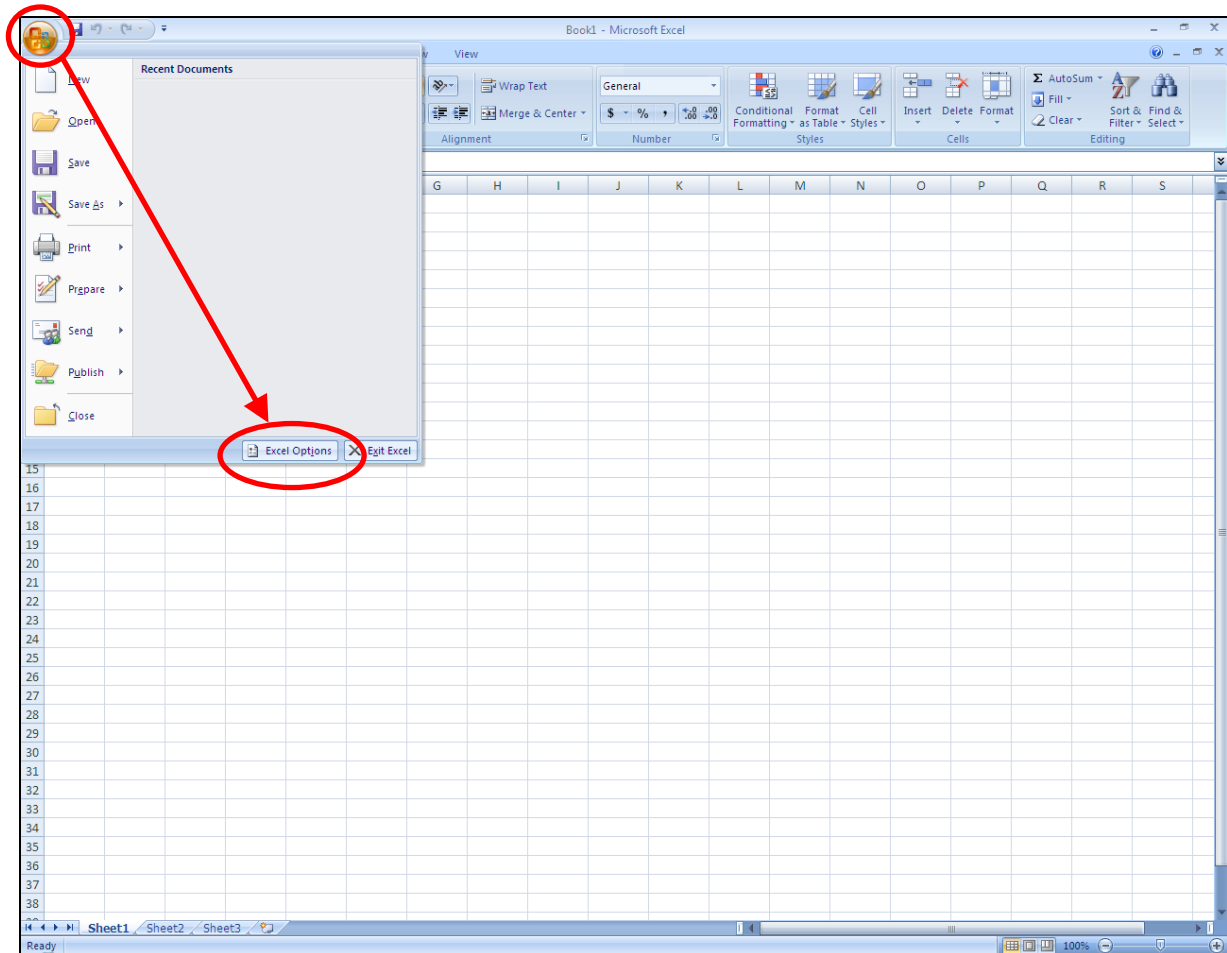


Figure 2.6: Registering FluidEXL *Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

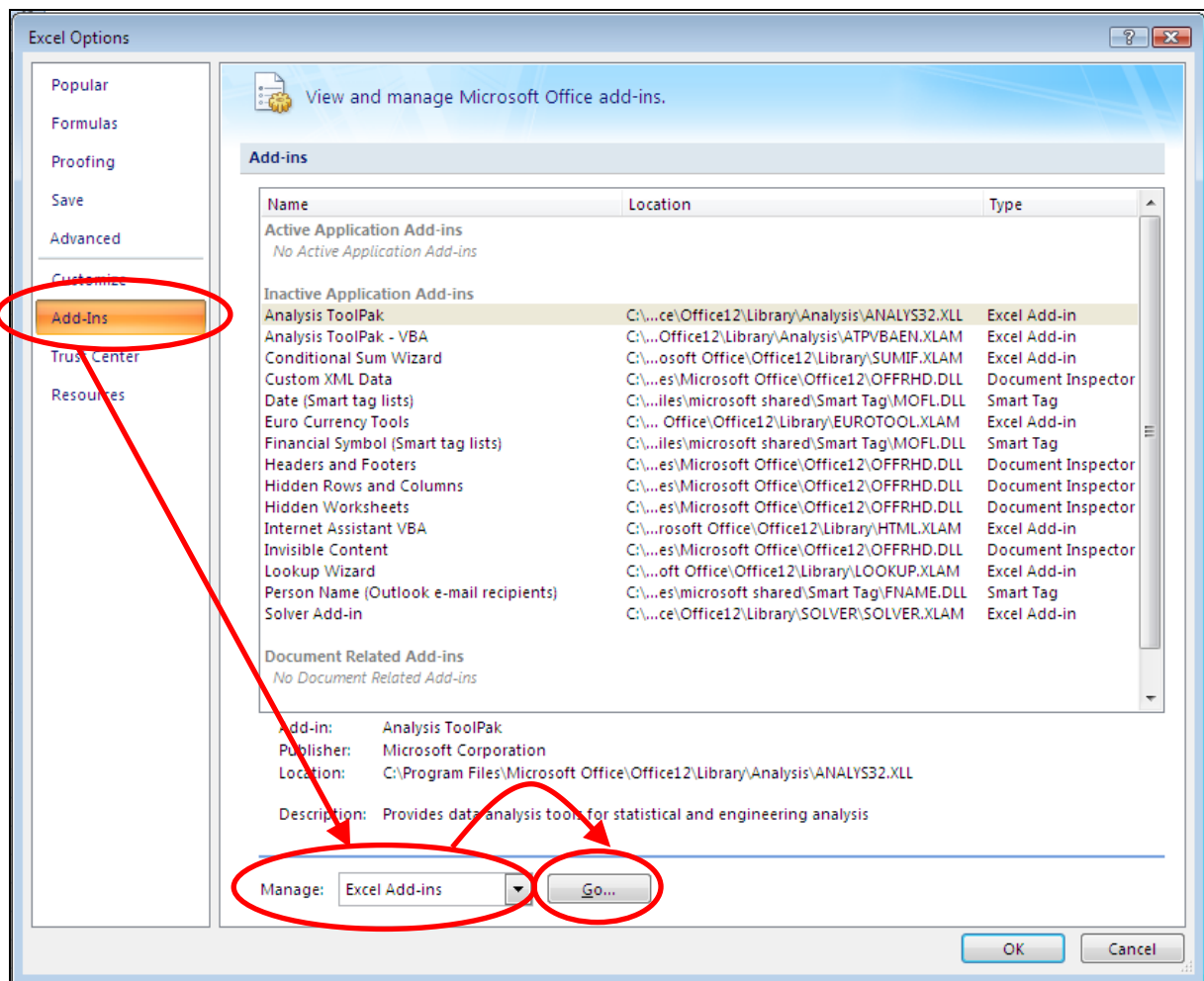


Figure 2.7: Dialog window "Excel Options"

- Should it not be shown in the list automatically, select "Excel Add-ins" (found next to "Manage:" in the lower area of the menu)
- Then click the "Go..." button
- Click "Browse" in the following window and locate the destination folder, generally
C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows);
within that folder click on the file named
"FluidEXL_Graphics_Eng.xla" (for English version of Windows)
"FluidEXL_Graphics.xla" (for German version of Windows)
and then hit "OK."

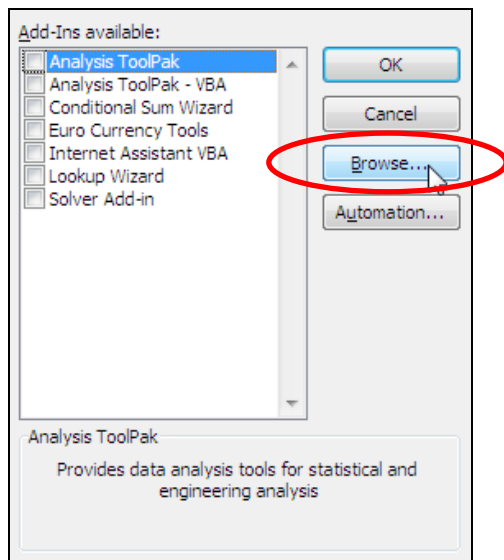


Figure 2.8: Dialog window "Add-Ins available"

- Now, "FluidEXL Graphics Eng" will be shown in your list of Add-Ins.
(If a check-mark is situated in the box next to the name "FluidEXL Graphics Eng," this Add-In will automatically be loaded whenever Excel® starts. This will continue to occur unless the check-mark is removed from the box by clicking on it.)

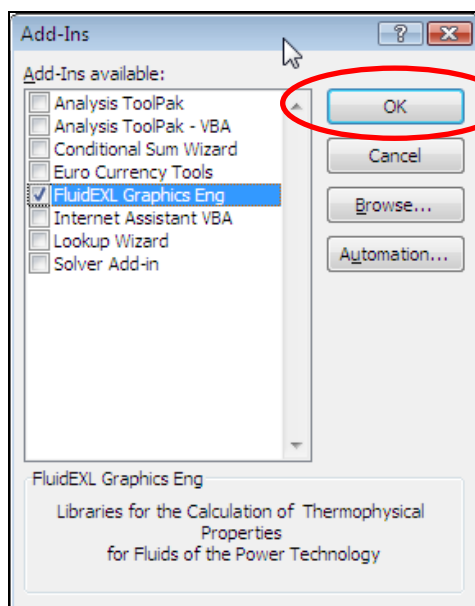


Figure 2.9: Dialog window "Add-Ins"

- In order to register the Add-In click the "OK" button in the "Add-Ins" window.

In order to use FluidEXL *Graphics* in the following example, click on the menu item "Add-Ins" shown in Figure 2.10.

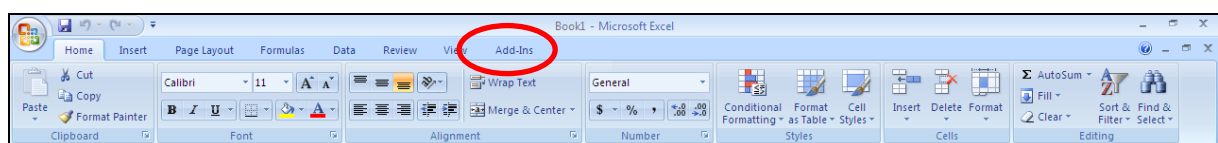


Figure 2.10: Menu item "Add-Ins"

In the upper menu region of Excel, the FluidEXL *Graphics* menu bar will appear as marked with the red circle in the next figure.

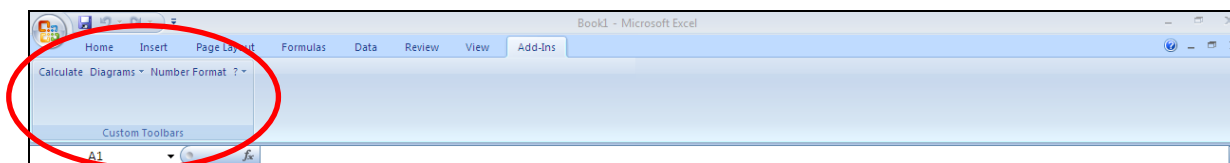


Figure 2.11: FluidEXL *Graphics* menu bar

Installation of FluidEXL *Graphics* in Excel® (versions 2007 and later) is now finished. FluidEXL *Graphics* can be used analogous to the description for using with earlier Excel® versions.

Adding the LibHeatEx Library (FluidEXL *Graphics* is already installed)

If FluidEXL *Graphics* has already been installed in the June 2010 version, you only have to copy the following files

FluidEXL_Graphics_Eng.xla	(for English version of Windows)
FluidEXL_Graphics.xla	(for German version of Windows)
LibHeatEx.dll	
LibHeatEx.hlp	

provided in the extracted folder

CD_FluidEXL_Graphics_LibHeatEx_Eng	(for English version of Windows)
CD_FluidEXL_Graphics_LibHeatEx	(for German version of Windows)

into the folder you have chosen for the installation of FluidEXL *Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng	(for English version of Windows)
C:\Programme\FluidEXL_Graphics	(for German version of Windows)

using an appropriate program such as Explorer® or Norton Commander.

From within Excel you can now select the "LibHeatEx" DLL library property functions for heat exchangers via this menu bar (the example calculation can be found in chapter 2.5 on page 2/19).

2.3 The FluidEXL *Graphics* Help System

As mentioned earlier, FluidEXL *Graphics* also provides detailed online help functions.

If you are running Windows Vista or Windows 7, please note the paragraph

"Using the FluidEXL *Graphics* Online-Help in Windows Vista or Windows 7."

For general information in Excel®

- Click on "?" and then "Help" in the FluidEXL *Graphics* menu bar.

Information on individual property functions may be accessed via the following steps:

- Click "Calculate" in the FluidEXL *Graphics* menu bar.
- Click on the "LibHeatEx" property library under "Or select a category:" in the "Insert Function" window which will appear.
- Click the "Help on this function" button in the lower left-hand edge of the "Insert Function" window.
- If the "Office Assistant" is active, first double-click "Help on this feature" and in the next

menu click "Help on selected function".

If the LibHeatEx.hlp function help cannot be found, confirm the question whether you want to look for it yourself with "Yes". Select the LibHeatEx.hlp file in the installation folder of FluidEXL *Graphics* in the window which is opened, in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows)

and click "Yes" in order to complete the search.

Using the FluidEXL *Graphics* Online Help in Windows Vista or Windows 7

If you are running Windows Vista or Windows 7 on your computer, you might not be able to open Help files. To view these files you have to install the Microsoft® Windows Help program which is provided by Microsoft®. Please carry out the following steps in order to download and install the Windows Help program.

Open Microsoft Internet Explorer® and go to the following address:

<http://support.microsoft.com/kb/917607/>

You will see the following web page:



Figure 2.12: Microsoft® Support web page

Scroll down until you see the headline "Resolution." Here you can see the bold hint:

"Download the appropriate version of Windows Help program (WinHlp32.exe), depending on the operating system that you are using:"

The following description relates to Windows® 7. The procedure is analogous for Windows® Vista.

Click on the link "Windows Help program (WinHlp32.exe) for Windows 7" (see Figure 2.13).

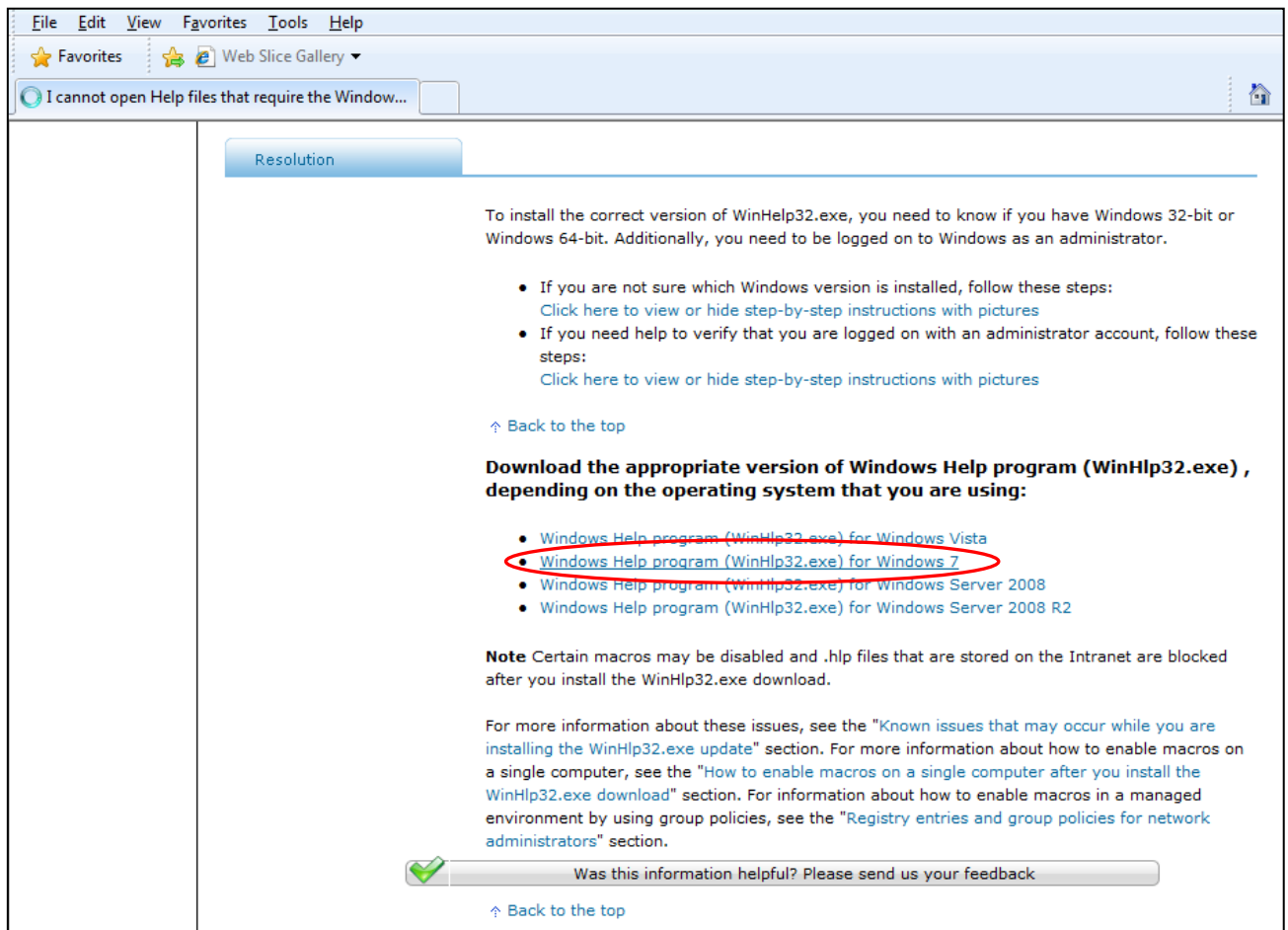


Figure 2.13: Selecting your Windows version

You will be forwarded to the Microsoft Download Center where you can download the Microsoft Windows Help program.

First, a validation of your Windows License is required.

To do this click on the "Continue" button (see Figure 2.14).

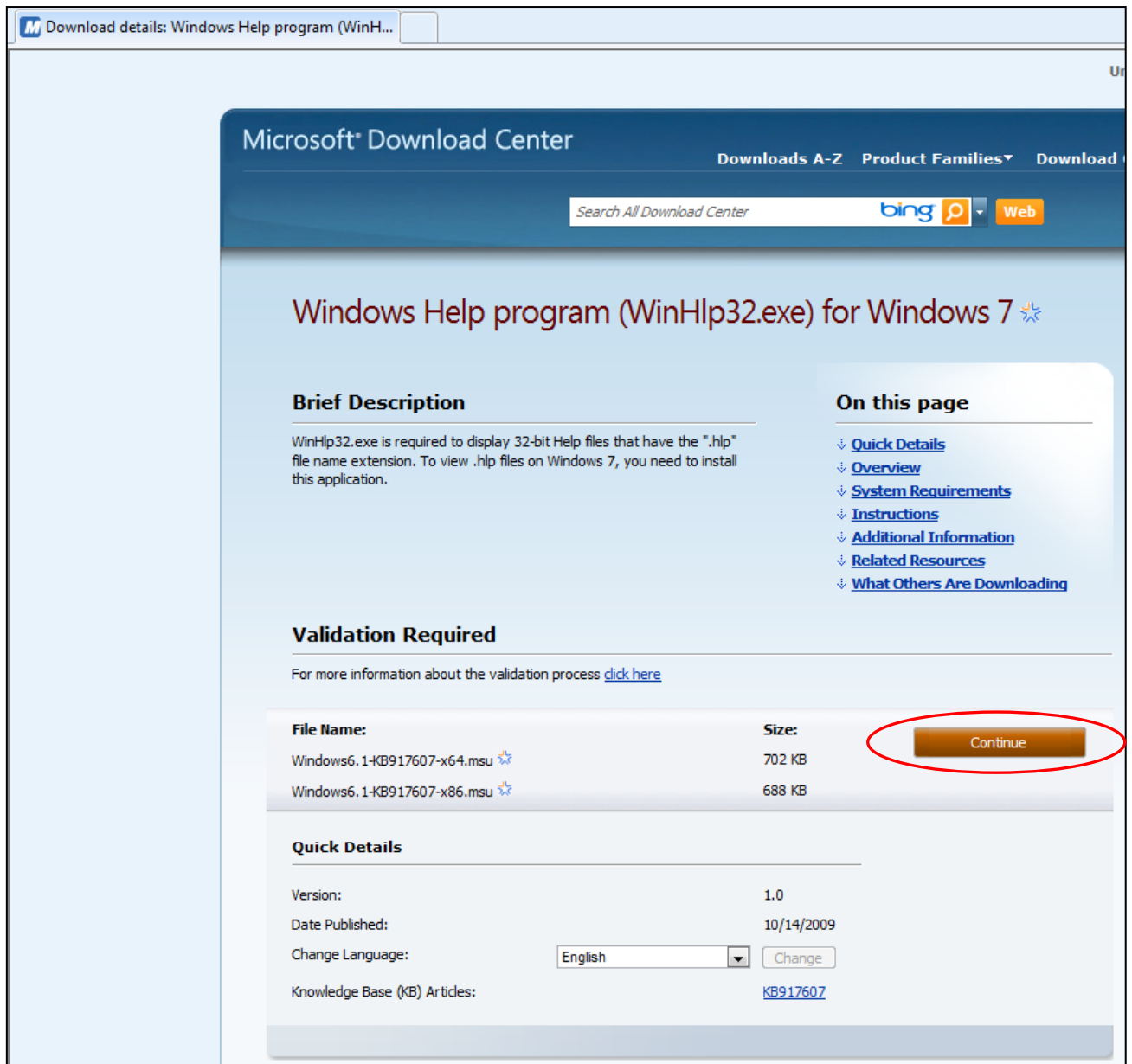


Figure 2.14: Microsoft® Download Center

You will be forwarded to a web page with instructions on how to install the Genuine Windows Validation Component.

At the top of your Windows Internet Explorer you will see a yellow information bar. Right-click this bar and select "Install ActiveX Control" in the context menu (see Figure 2.15).

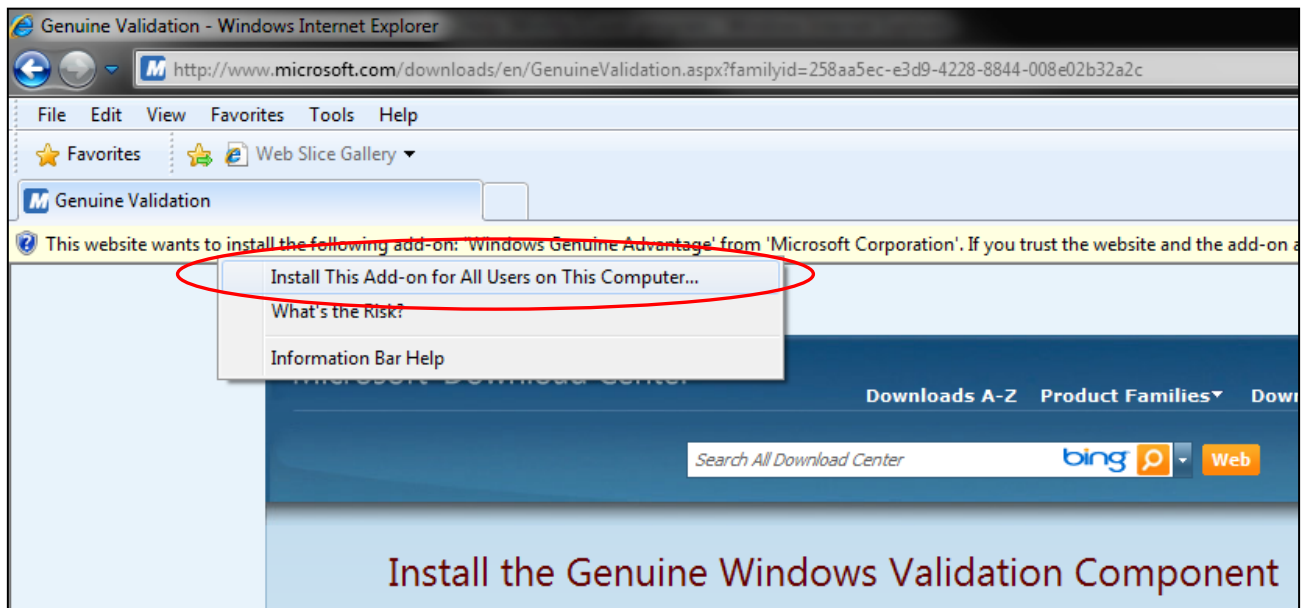


Figure 2.15: Installing the Genuine Windows Validation Component

A dialog window appears in which you will be asked if you want to install the software. Click the "Install" button to continue (see Figure 2.16).

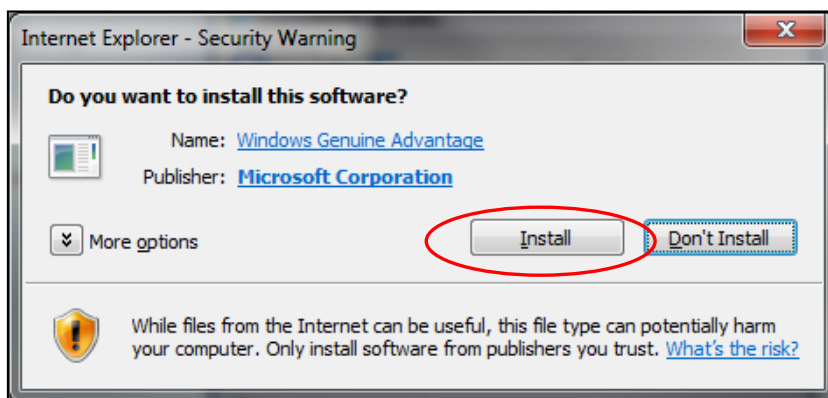


Figure 2.16: Internet Explorer – Security Warning

After the validation has been carried out you will be able to download the appropriate version of Windows Help program (see Figure 2.17).

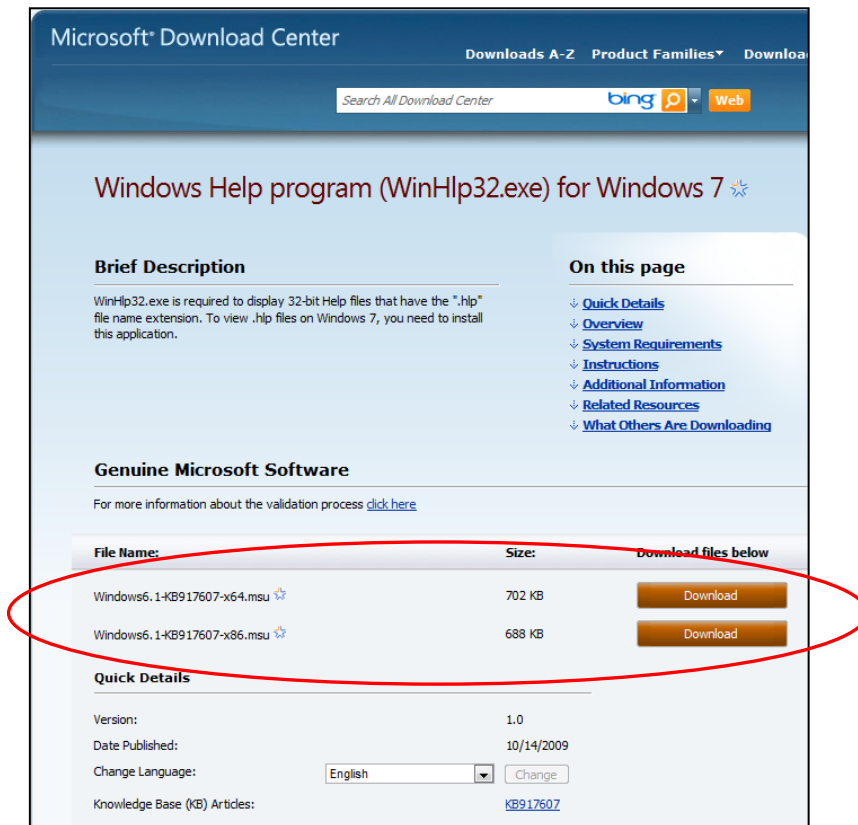


Figure 2.17: Downloading the Windows Help program

To download and install the correct file you need to know which Windows version (32-bit or 64-bit) you are running on your computer.

If you are running a 64-bit operating system, please download the file
Windows6.1-KB917607-x64.msu.

If you are running a 32-bit operating system, please download the file
Windows6.1-KB917607-x86.msu.

In order to run the installation of the Windows Help program double-click the file you have just downloaded on your computer:

Windows6.1-KB917607-x64.msu (for 64-bit operating system)

Windows6.1-KB917607-x86.msu. (for 32-bit operating system).

Installation starts with a window searching for updates on your computer. After the program has finished searching you may see the following window.

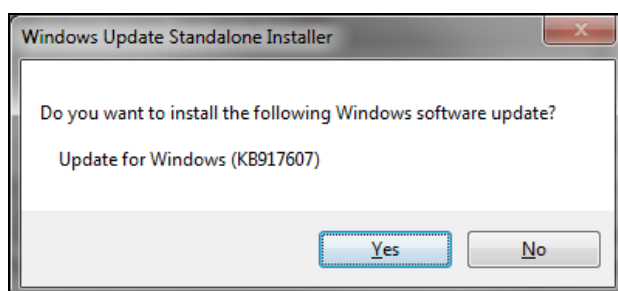


Figure 2.18: Windows Update Standalone Installer

In this case, the installation can be continued by clicking the "Yes" button.
(If you have already installed this update, you will see the message "Update for Windows (KB917607) is already installed on this computer.")

In the next window you have to accept the Microsoft license terms before installing the update by clicking on "I Accept" (see Figure 2.19)

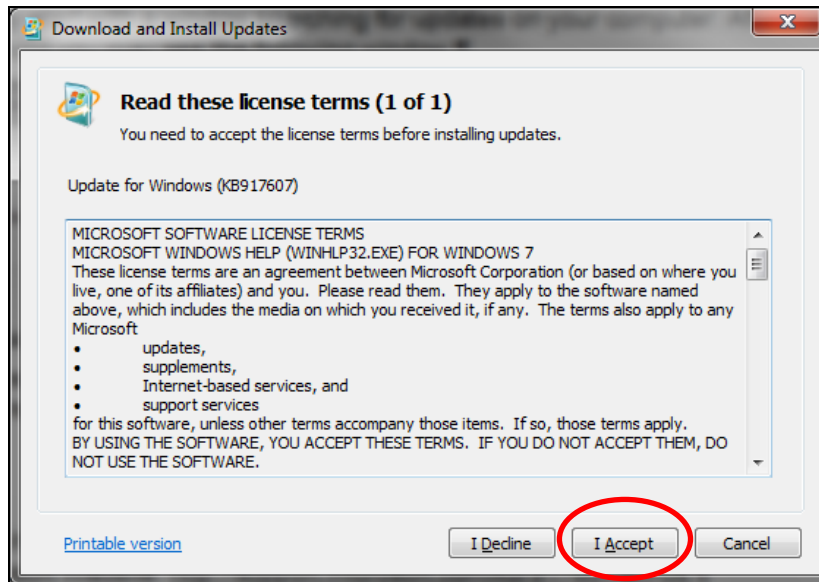


Figure 2.19: Windows License Terms

Installation starts once you have clicked the "I Accept" button (see Figure 2.20).

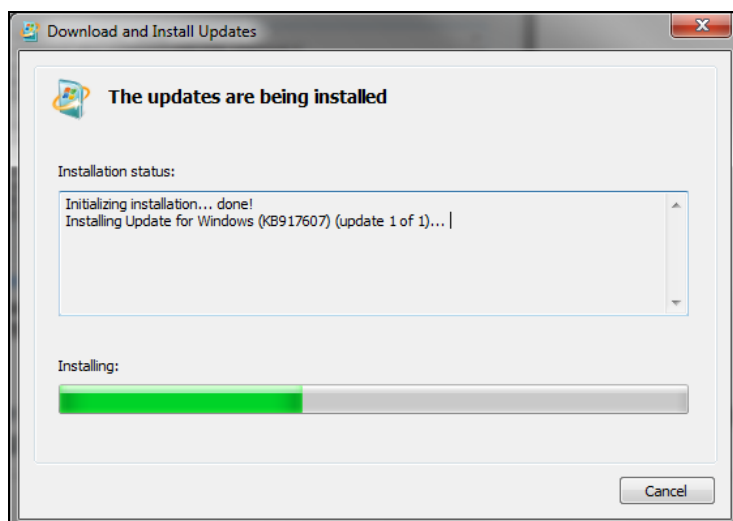


Figure 2.20: Installation process

After the Windows Help program has been installed, the notification "Installation complete" will appear. Confirm this by clicking the "Close" button.

The installation of the Windows Help program has been completed and you will now be able to open the Help files.

2.4 Licensing the LibHeatEx Property Library

The licensing procedure has to be carried out when Excel[®] starts up and a FluidEXL *Graphics* prompt message appears. In this case, you will see the "License Information" window (see figure below).

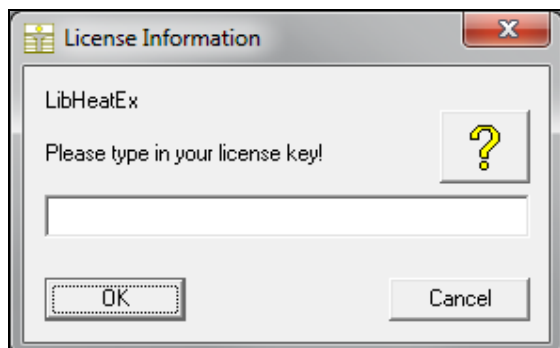


Figure 2.21: "License Information" window

Here you will have to type in the license key which you have obtained from the Zittau/Goerlitz University of Applied Sciences. You can find contact information on the "Content" page of this User's Guide or by clicking the yellow question mark in the "License Information" window. Then the following window will appear:

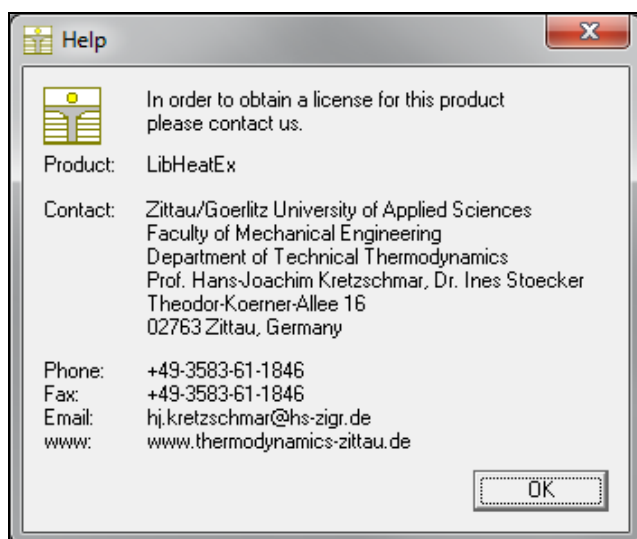


Figure 2.22: "Help" window

If you do not enter a valid license it is still possible to start Excel by clicking "Cancel" twice. In this case, the LibHeatEx property library will display the result "-1111111" for every calculation.

The "License Information" window will appear every time you start Excel unless you uninstall FluidEXL *Graphics* according to the description in section 2.6 of this User's Guide.

Should you not wish to license the LibHeatEx property library, you have to delete the files
 LibHeatEx.dll
 LibHeatEx.hlp

in the installation folder of FluidEXL *Graphics* (the standard being

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)

C:\Programme\FluidEXL_Graphics (for German version of Windows)

using an appropriate program such as Explorer[®] or Norton Commander.

2.5 Example: Calculation of $\Phi_A = f\left(I_{TYPE}, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, N_{SPEC}\right)$

Now we will calculate, step by step, the dimensionless temperature changes ϕ of the countercurrent flow heat exchanger as a function of I_{TYPE} , number of transfer units, heat capacity rate ratios and N_{SPEC} , using FluidEXL *Graphics*.

The following quantities are given:

$$\frac{k \cdot A}{\dot{C}_A} = 1.00$$

$$\frac{\dot{C}_A}{\dot{C}_B} = 0.5$$

I_{TYPE} and N_{SPEC} can be obtained from Table 1.

Type of heat exchanger: $I_{TYPE} = 1$

Number of tube rows or passes: $N_{SPEC} = 0$

- Start Excel®
- Enter the value for I_{TYPE} in a cell
⇒ e. g.: Enter the value 1 into cell A2
- Enter a value for $\frac{k \cdot A}{\dot{C}_A}$ in a cell
⇒ e. g.: Enter the value 1.00 into cell B2
- Enter a value for $\frac{\dot{C}_A}{\dot{C}_B}$ in a cell
⇒ e. g.: Enter the value 0.50 into cell C2
- Enter a value for N_{SPEC} in a cell
⇒ e. g.: Enter the value 0 into cell D2
- Click the cell in which the value of the dimensionless temperature changes ϕ is to be displayed.
⇒ e.g.: Click the E2 cell.
- Click "Calculate" in the menu bar of FluidEXL *Graphics*.
Now the "Insert Function" window appears (see Figure 2.23).

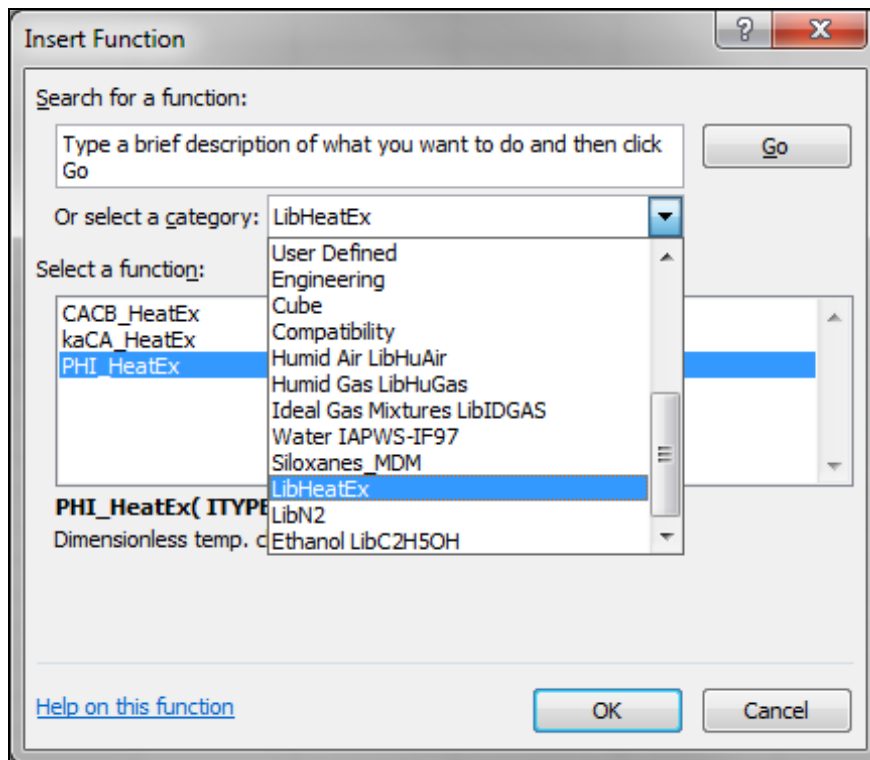


Figure 2.23: Choice of library and function name

- Search and click the "LibHeatEx" library under "Or select a category:" in the upper part of the window.
 - Search and click the PHI_HeatEx function under "Select a function:" right below.
- Here it is possible to get more information on the range of validity, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".
- The window shown in Figure 2.24 will now appear.

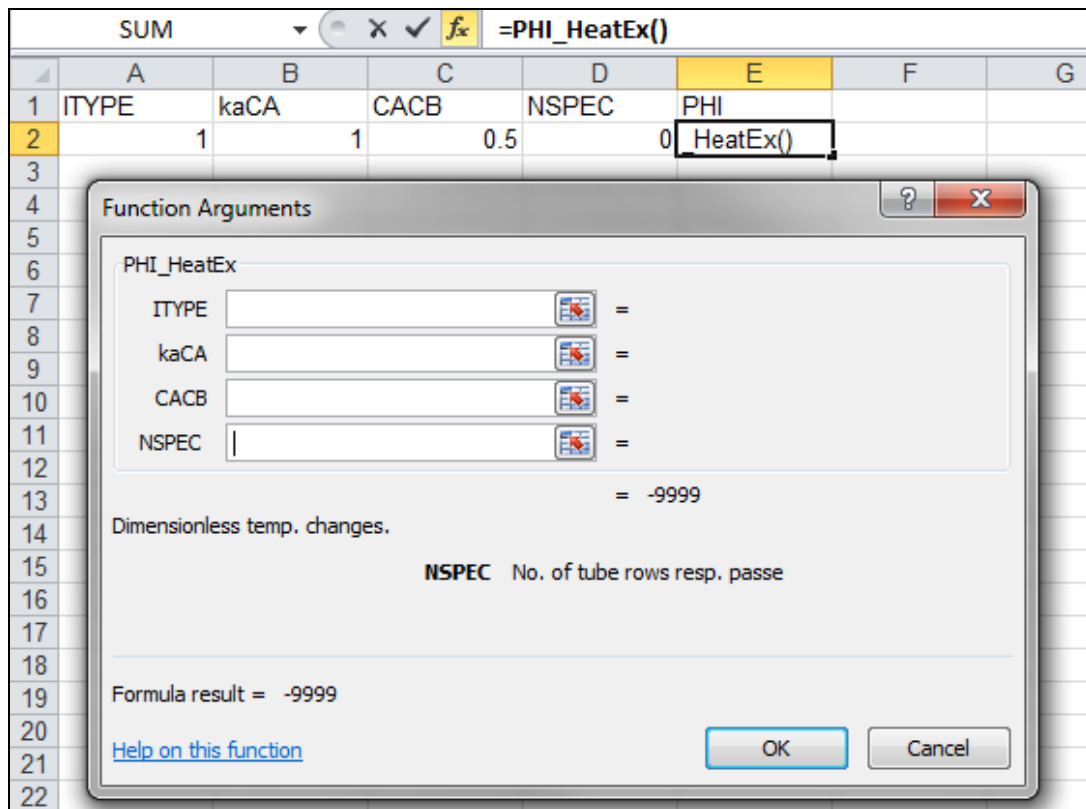


Figure 2.24: Input menu for the function

- The Cursor is now situated on the line next to "ITYPE". You can now enter the value for *ITYPE* either by clicking the cell with the value for *ITYPE*, by entering the name of the cell with the value for *ITYPE*, or by entering the value for *ITYPE* directly.

⇒ e. g.: Click on the cell A2

- Situate the cursor next to "kaCA" and enter the value for *kaCA* by clicking the cell with the value for *kaCA*, by entering the name of the cell with the value for *kaCA*, or by entering the value for *kaCA* directly.

⇒ e. g.: Type B2 into the window next to "kaCA"

- Situate the cursor next to "CACB" and enter the value for *CACB* by clicking the cell with the value for *CACB*, by entering the name of the cell with the value for *CACB*, or by entering the value for *CACB* directly.

⇒ e. g.: Click on the cell C2

- The Cursor is now situated on the line next to "NSPEC". You can now enter the value for *NSPEC* either by clicking the cell with the value for *NSPEC*, by entering the name of the cell with the value for *NSPEC*, or by entering the value for *NSPEC* directly.

⇒ e. g.: Click on the cell D2

The window should now look like the following figure:

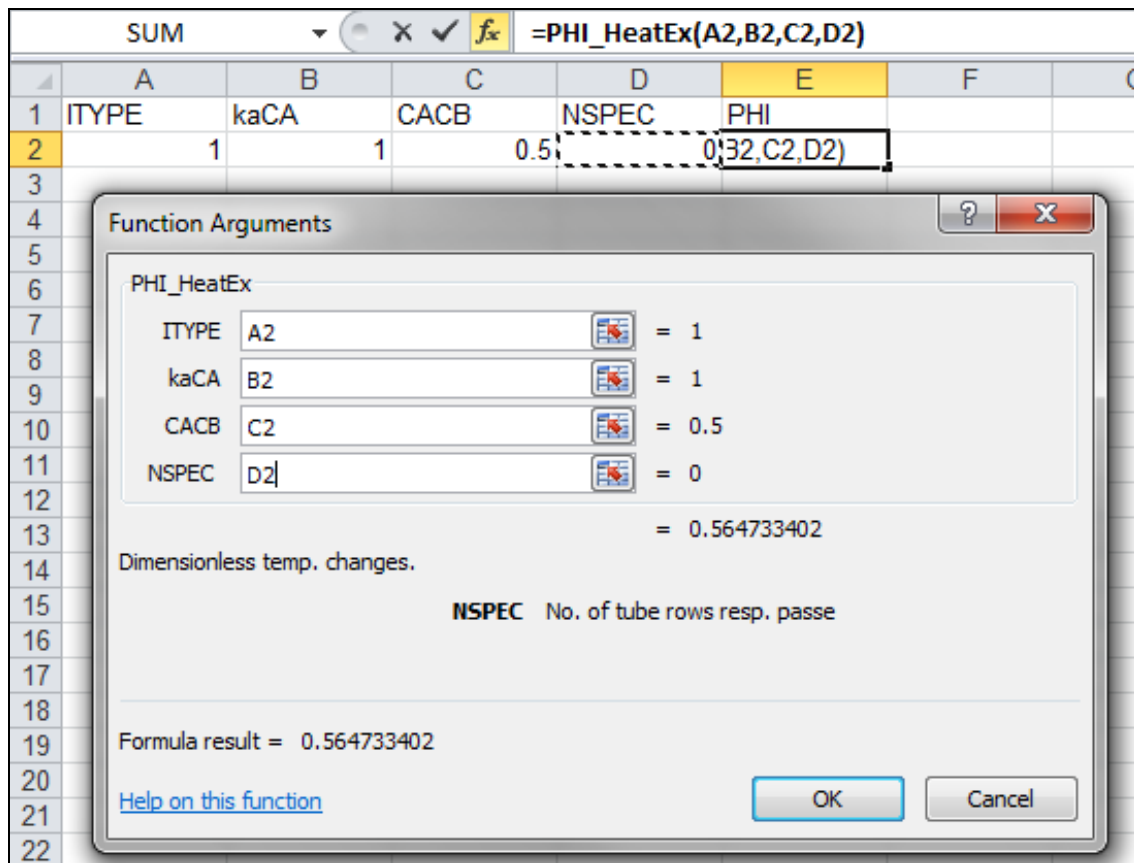


Figure 2.25: Input menu showing the result

- Click the "OK" button.

The result for ϕ appears in the cell selected above.

⇒ The result in our sample calculation here is:
dimensionless temperature changes $\phi = 0.564733402$.

The calculation of Φ has thus been completed.

You can now arbitrarily change the values for I_{TYPE} , $\frac{k \cdot A}{\dot{C}_A}$, $\frac{\dot{C}_A}{\dot{C}_B}$ and N_{SPEC} in the appropriate

cells. The dimensionless temperatures changes are recalculated and updated every time you change the data. This shows that the Excel® data flow and the DLL calculations are working together successfully.

Note:

If the calculation results in -1 , this indicates that the values entered are located outside the range of validity of LibHeatHex. More detailed information on each function and its range of validity is available in Chapter 3.

For further property functions calculable in FluidEXL^{Graphics}, see the function table in Chapter 1.

Number Formats

When using FluidEXL *Graphics* you have the option of choosing special number formats in advance.

Changes can be made as follows:

- Click the cell or select and click on the cells you wish to format.
(In empty cells the new format will be applied once a value has been entered.)
- Click "Number Format" in the FluidEXL *Graphics* menu bar.
- Select the desired number format in the dialog box which appears:
 - "STD – Standard": Insignificant zeros behind the decimal point are not shown.
 - "FIX – Fixed Number of Digits": All set decimal places are shown, including insignificant zeros.
 - "SCI – Scientific Format": Numbers are always shown in the exponential form with the set number of decimal places.
- Set the "Number of decimal places" by entering the number into the appropriate window.
- Confirm this by clicking the "OK" button.

As an example, the table below shows the three formats for the number 1.230 adjusted for three decimal places:

STD	1.23
FIX	1.230
SCI	1.230E+00

This formatting can also be applied to cells which have already been calculated.

2.6 Removing FluidEXL *Graphics*

Should you wish to remove only the LibHeatEx library, delete the files

LibHeatEx.dll
LibHeatEx.hlp

in the directory selected for the installation of FluidEXL *Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows)

by using an appropriate program such as Explorer®, Windows, or Norton Commander.

Unregistering FluidEXL *Graphics* as Add-In in Excel®, versions 2003 or earlier

To remove FluidEXL *Graphics* completely, proceed as follows: First the registration of

FluidEXL_Graphics_Eng.xla (for English version of Windows)
FluidEXL_Graphics.xla (for German version of Windows)

has to be cancelled in Excel®.

In order to do that, click "Tools" in the upper menu bar of Excel and here "Add-Ins...". Untick the box on the left-hand side of

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

in the window that appears and click the "OK" button. The additional menu bar of FluidEXL *Graphics* disappears from the upper part of the Excel window. Afterwards, we recommend closing Excel.

If the FluidEXL *Graphics* menu bar does not disappear, take the following steps:

Click "View" in the upper menu bar of Excel, then "Toolbars" and then "Customize..." in the list box which appears.

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

is situated at the bottom of the "Toolbars" entries, which must be selected by clicking on it. Delete the entry by clicking "Delete". You will be asked whether you really want to delete the toolbar – click "OK".

Within the next step delete the files

LibHeatEx.dll
LibHeatEx.hlp

in the directory selected for the installation of FluidEXL *Graphics* (in the standard case

C:\Program Files\FluidEXL_Graphics_Eng (for English version of Windows)
C:\Programme\FluidEXL_Graphics (for German version of Windows),

using an appropriate program such as Explorer® or Norton Commander.

In order to remove FluidEXL *Graphics* from Windows and the hard disk drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel". Now double-click on "Add or Remove Programs". In the list box of the "Add/Remove Programs" window that appears select

"FluidEXL Graphics Eng" (for English version of Windows)
"FluidEXL Graphics" (for German version of Windows)

by clicking on it and click the "Add/Remove..." button. In the following dialog box click "Automatic" and thereafter "Next >". Click "Finish" in the "Perform Uninstall" window. Answer the question whether all shared components shall be removed with "Yes to All". Finally, close the "Add/Remove Programs" and "Control Panel" windows.

Now FluidEXL *Graphics* has been removed.

Unregistering FluidEXL *Graphics* as Add-In in Excel® 2007 (or later versions)

In order to unregister the FluidEXL *Graphics* Add-In in Excel® 2007 start Excel and carry out the following commands:

- Click the Windows Office® button in the upper left corner of Excel
- Click on the "Excel Options" button in the menu which appears

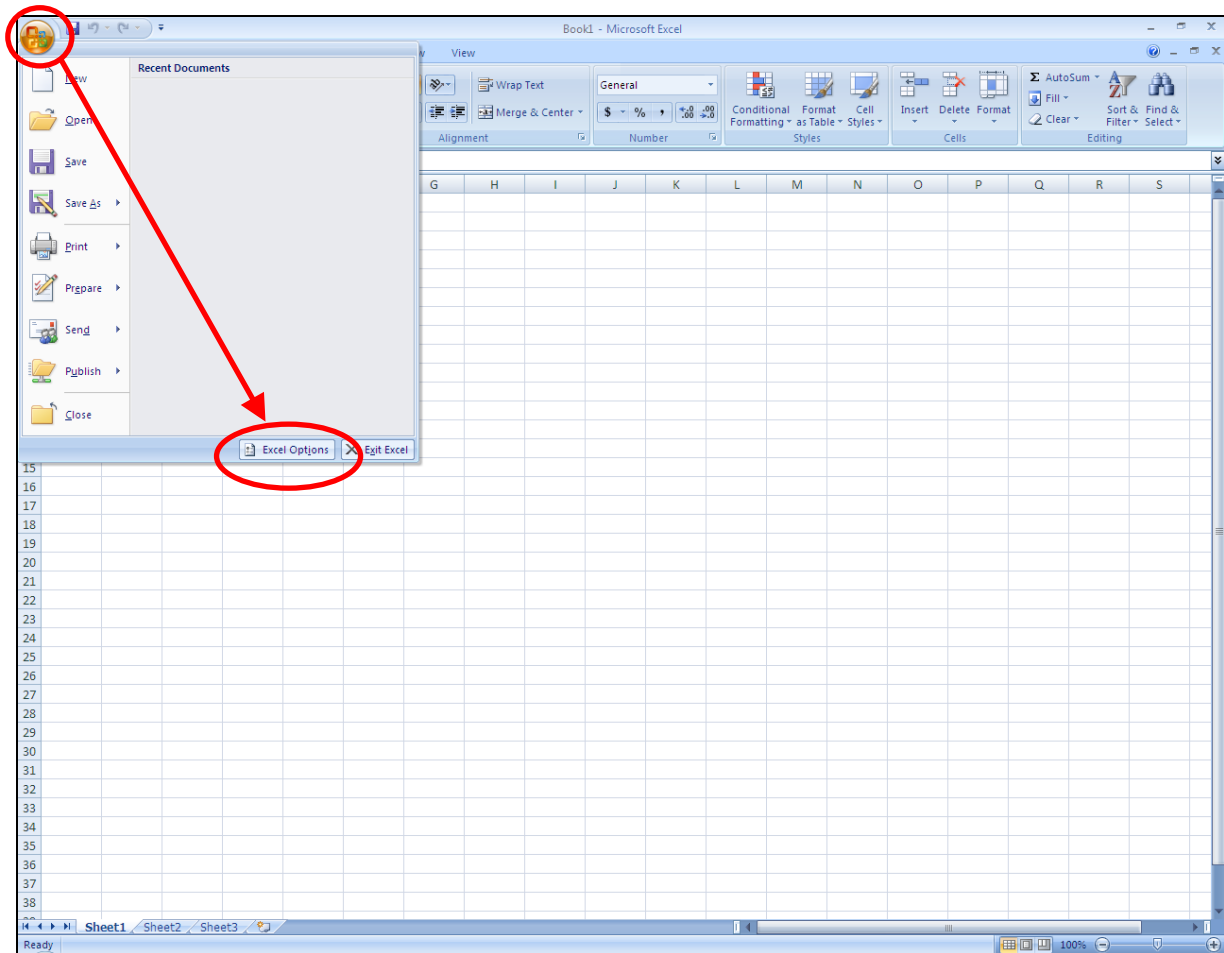


Figure 2.28: Unregistering FluidEXL *Graphics* as Add-In in Excel® 2007

- Click on "Add-Ins" in the next menu

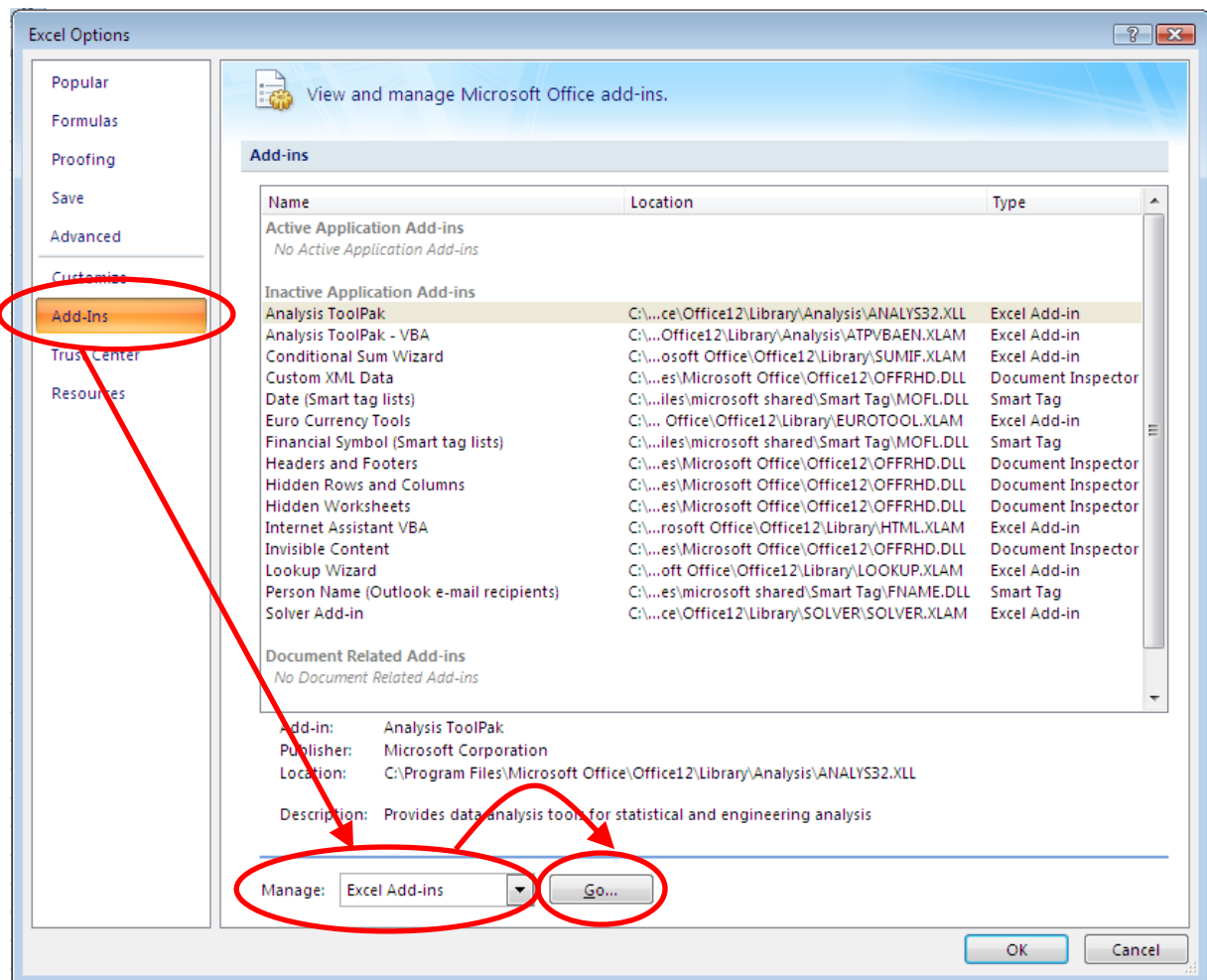


Figure 2.29: Dialog window "Add-Ins"

- If it is not shown in the list automatically, chose and click "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Afterwards click the "Go..." button
- Remove the checkmark in front of
 "FluidEXL Graphics Eng" (for English version of Windows)
 "FluidEXL Graphics" (for German version of Windows)
 in the window which now appears. Click the "OK" button to confirm your entry.

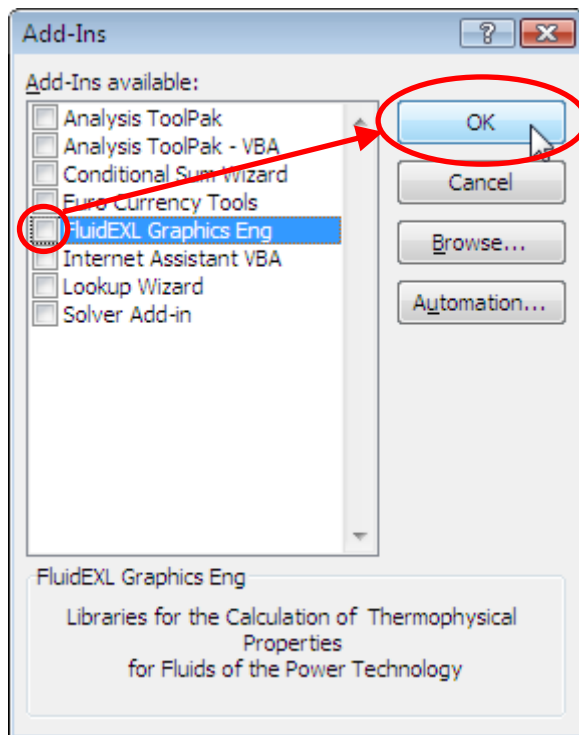


Figure 2.30: Dialog window "Add-Ins"

In order to remove FluidEXL^{Graphics} from Windows and the hard drive, click "Start" in the Windows task bar, select "Settings" and click "Control Panel."

Now, double click on "Add or Remove Programs."

In the list box of the "Add or Remove Programs" window that appears, select

"FluidEXL Graphics Eng" (for English version of Windows)

"FluidEXL Graphics" (for German version of Windows)

by clicking on it and then clicking the "Add/Remove..." button.

Click "Automatic" in the following dialog box and then the "Next >" button.

Click "Finish" in the "Perform Uninstall" window.

Answer the question of whether all shared components should be removed with "Yes to All."

Finally, close the "Add or Remove Programs" and "Control Panel" windows.

Now FluidEXL^{Graphics} has been completely removed from your computer.

3. Program Documentation

Dimensionless Temperature Changes: $\Phi = f\left(ITYPE, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, NSPEC\right)$

Function Name: **Phi_HeatEx**
 Declaration for DLL: **PHI_HeatEx (ITYPE,kaCA,CACB,NSPEC)**
 Fortran 77 Subprogram: **REAL*8 FUNCTION**
PHI_HeatEx (ITYPE, kaCA, CACB, NSPEC)
REAL*8 kaCA, CACB
INTEGER*4 ITYPE, NSPEC

Input values

Type of heat exchanger	<i>ITYPE</i>	
Number of transfer units	$kaCA = \frac{k \cdot A}{\dot{C}_A}$	A – heating surface k - heat transfer coefficient
Heat capacity rate ratios	$CACB = \frac{\dot{C}_A}{\dot{C}_B}$	$\dot{C}_A$ - heat capacity rate ratios stream A $\dot{C}_B$ - heat capacity rate ratios stream B
Number of tube rows or passes	<i>NSPEC</i>	

Result

PHI_HeatEx – Dimensionless temperature changes

$$\Phi = Phi = \frac{t_{A1} - t_{A2}}{t_{A1} - t_{B1}} = \frac{\Delta g_A}{\Delta g_{AB}^{max}}$$

A – stream A	1 – Inlet of A and B
B – stream B	2 – Outlet of A and B

Range of Validity

Number of transfer units:	$0 < kaCA$
Heat capacity rate ratios:	$0 \leq CACB$
Type of heat exchanger:	$0 < ITYPE \leq 24$
Number of tube rows or passes:	$0 = NSPEC$ for ITYPE 1-9; 12-19; 21-24 $0 < NSPEC$ for ITYPE 10; 11; 20

Results for wrong input values

PHI_HeatEx = -9999

References: [1]

Number of Transfer Units: $\frac{k \cdot A}{\dot{C}_A} = f\left(ITYPE, \Phi, \frac{\dot{C}_A}{\dot{C}_B}, NSPEC\right)$

Function Name: **kaCA_HeatEx**
 Declaration for DLL: **kaCA_HeatEx (ITYPE,PHI,CACB,NSPEC)**
 Fortran 77 Subprogram: **REAL*8 FUNCTION**
kaCA_HeatEx(ITYPE,PHI,CACB,NSPEC)
REAL*8 PHI, CACB
INTEGER*4 ITYPE, NSPEC

Input values

Type of heat exchanger	<i>ITYPE</i>	
Dimensionless temperature changes	$\Phi = Phi = \frac{t_{A1} - t_{A2}}{t_{A1} - t_{B1}} = \frac{\Delta g_A}{\Delta g_{AB}^{max}}$	A – stream A B – stream B 1 – Inlet of A and B 2 – Outlet of A and B
Heat capacity rate ratios	$CACB = \frac{\dot{C}_A}{\dot{C}_B}$	$\dot{C}_A$ - heat capacity rate ratios stream A $\dot{C}_B$ - heat capacity rate ratios stream B
Number of tube rows or passes	<i>NSPEC</i>	

Result

kaCA_HeatEx– Number of transfer units

$kaCA = \frac{k \cdot A}{\dot{C}_A}$	A – heating surface
	k - heat transfer coefficient

Range of Validity

Dimensionless temperature changes:	$0 \leq Phi \leq 1$
Heat capacity rate ratios:	$0 \leq CACB$
Type of heat exchanger:	$0 < ITYPE \leq 24$
Number of tube rows or passes:	$0 = NSPEC$ for ITYPE 1-9; 12-19; 21-24 $0 < NSPEC$ for ITYPE 10; 11; 20

Results for wrong input values

kaCA_HeatEx = -9999

kaCA_HeatEx = -1 no result at iteration.

References: [1]

Heat Capacity Rate Ratios: $\frac{\dot{C}_A}{\dot{C}_B} = f\left(ITYPE, \Phi, \frac{k \cdot A}{\dot{C}_A}, NSPEC\right)$

Function Name: **CACB_HeatEx**
 Declaration for DLL: **CACB_HeatEx (ITYPE,PHI, kaCA,NSPEC)**
 Fortran 77 Subprogram: **REAL*8 FUNCTION**
CACB_HeatEx (ITYPE,PHI,kaCA,NSPEC)
 REAL*8 PHI, kaCA
 INTEGER*4 ITYPE, NSPEC

Input values

Type of heat exchanger	<i>ITYPE</i>	
Dimensionless temperature changes	$\Phi = Phi = \frac{t_{A1} - t_{A2}}{t_{A1} - t_{B1}} = \frac{\Delta g_A}{\Delta g_{AB}^{max}}$	A – stream A B – stream B 1 – Inlet of A and B 2 – Outlet of A and B
Number of transfer units	$kaCA = \frac{k \cdot A}{\dot{C}_A}$	A – heating surface k - heat transfer coefficient
Number of tube rows or passes	<i>NSPEC</i>	

Result

CACB_HeatEx – Heat capacity rate ratios

$$CACB = \frac{\dot{C}_A}{\dot{C}_B} = \frac{\Delta t_B}{\Delta t_A}$$

$\dot{C}_A$ - heat capacity rate ratios stream A
 $\dot{C}_B$ - heat capacity rate ratios stream B

Range of Validity

Dimensionless temperature changes:	$0 \leq Phi \leq 1$
Number of transfer units:	$0 < kaCA$
Type of Heat Exchanger:	$0 < ITYPE \leq 24$
Number of tube rows or passes:	$0 = NSPEC$ for ITYPE 1-9; 12-19; 21-24 $0 < NSPEC$ for ITYPE 10; 11; 20

Results for wrong input values

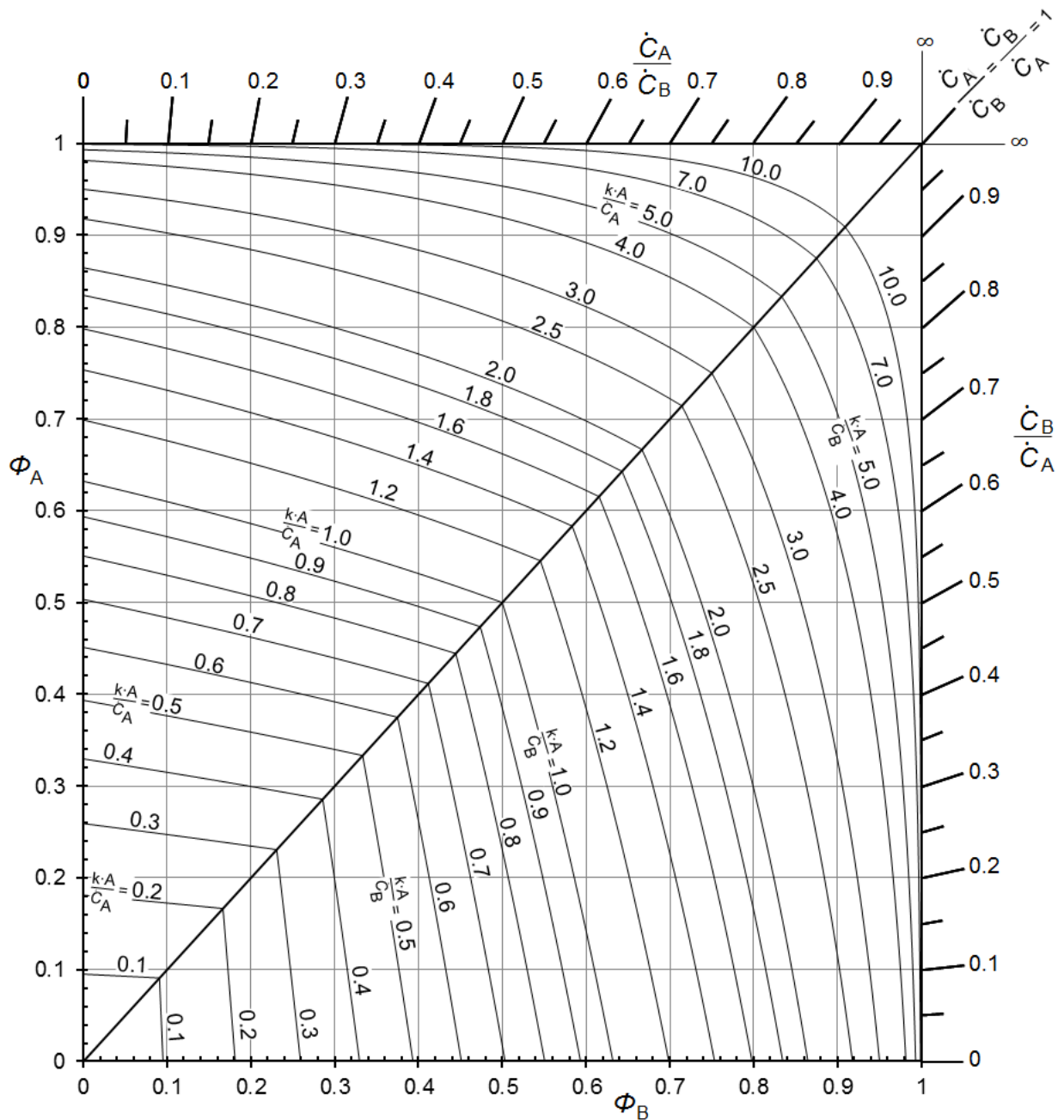
CACB_HeatEx = -9999

CACB_HeatEx = -1 no result at iteration.

References: [1]

4. Diagrams of Dimensionless Temperature Changes

Pure counter current flow
Calculated from VDI Heat Atlas 2010



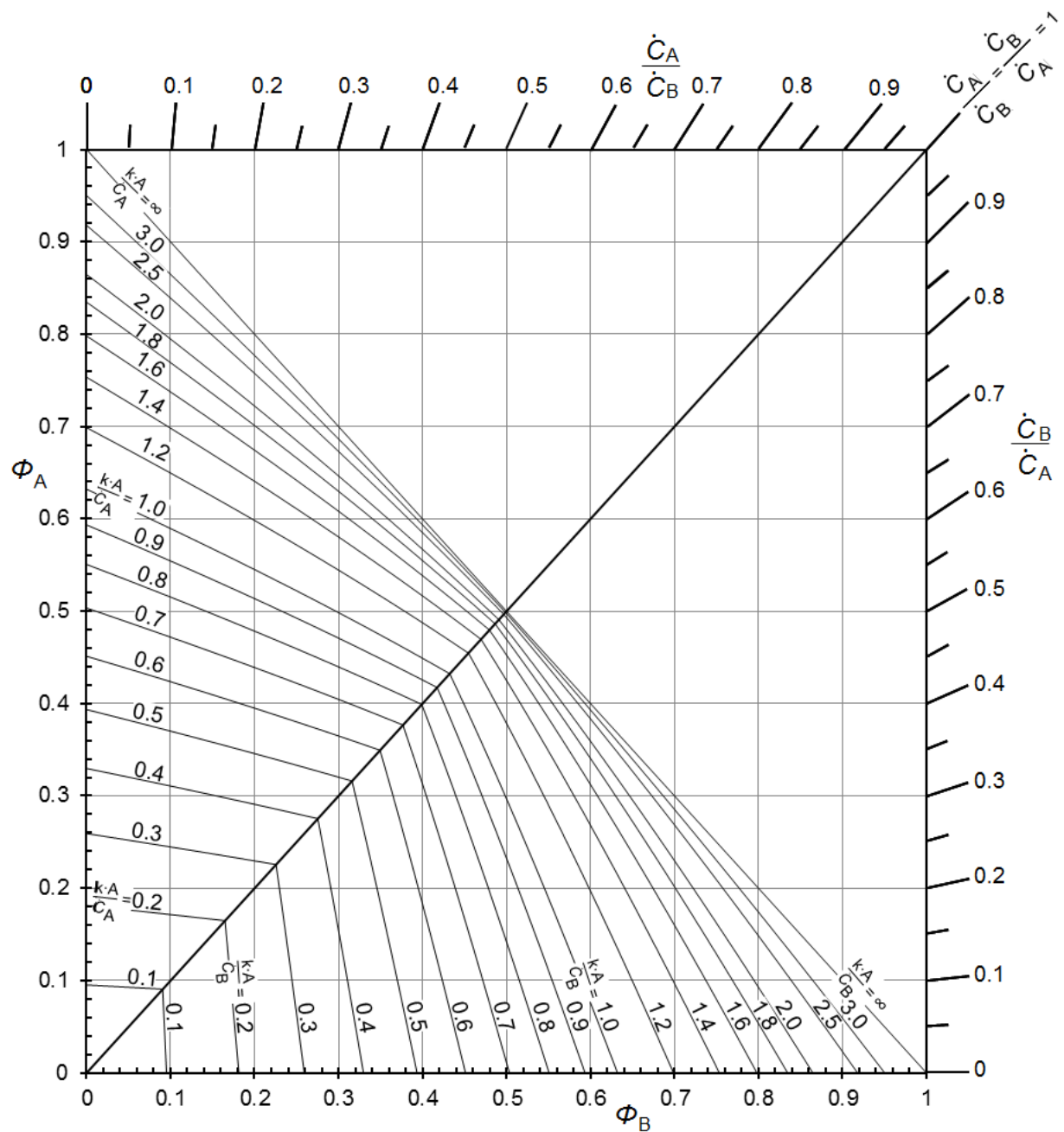
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Figure 5.1: Pure counter current flow - ITYPE 1

Pure cocurrent flow

Calculated from VDI Heat Atlas 2010

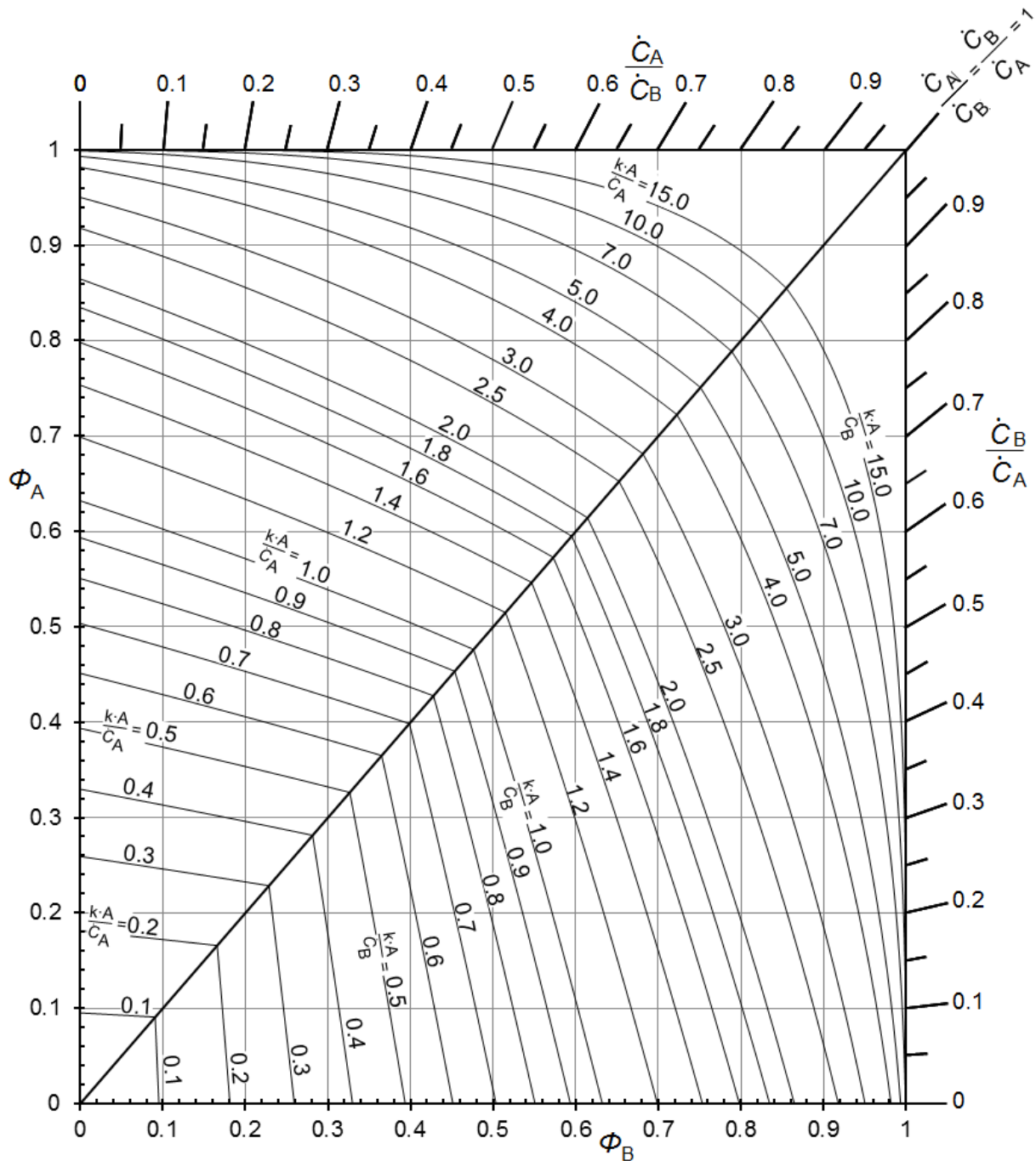


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Figure 5.2: Pure cocurrent flow - ITYPE 2

Pure cross-flow
Calculated from VDI Heat Atlas 2010

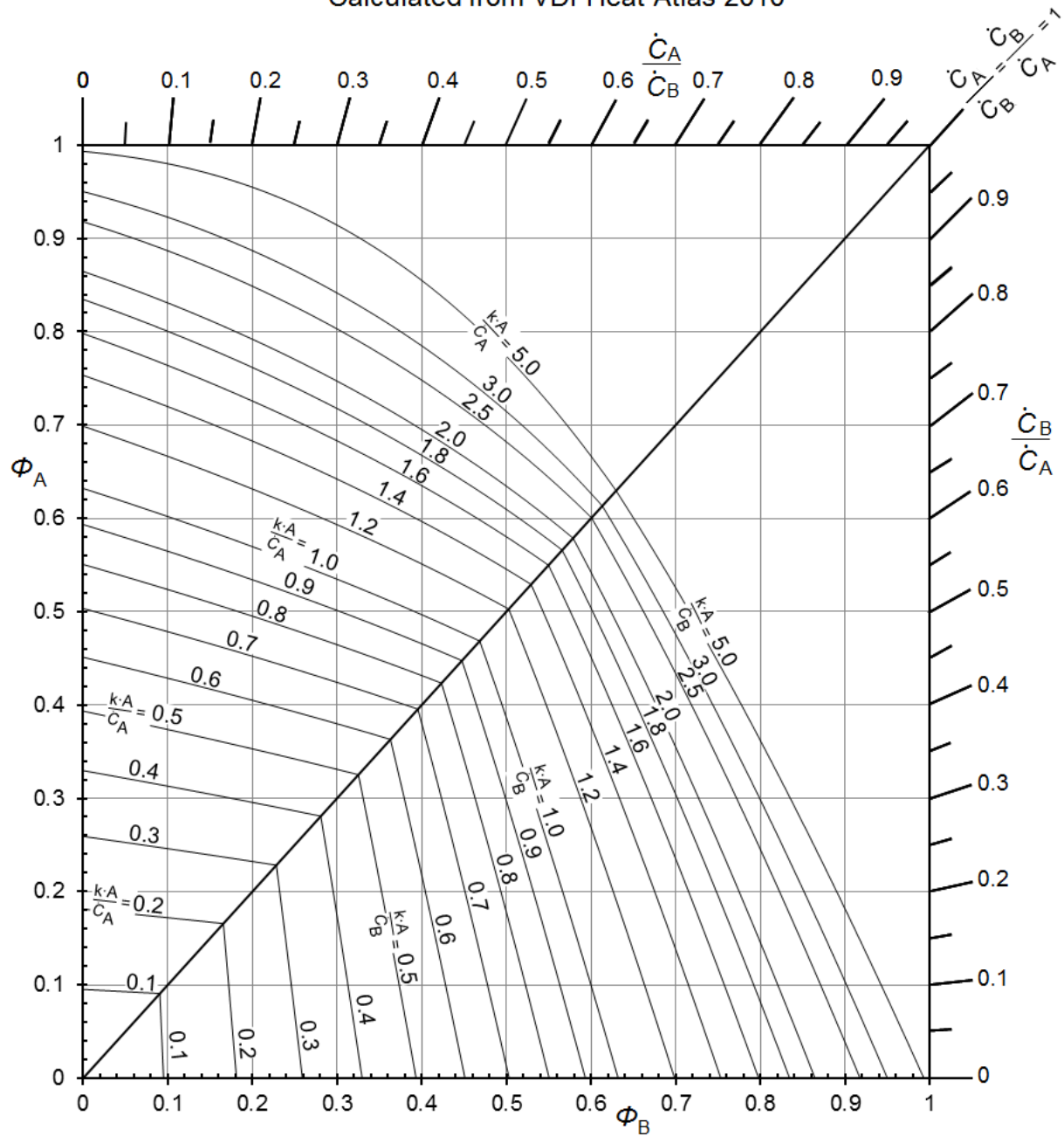


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Figure 5.3: Pure cross-flow - ITYPE 3

Cross-flow with one tube row,
laterally mixed on one side
Calculated from VDI Heat Atlas 2010

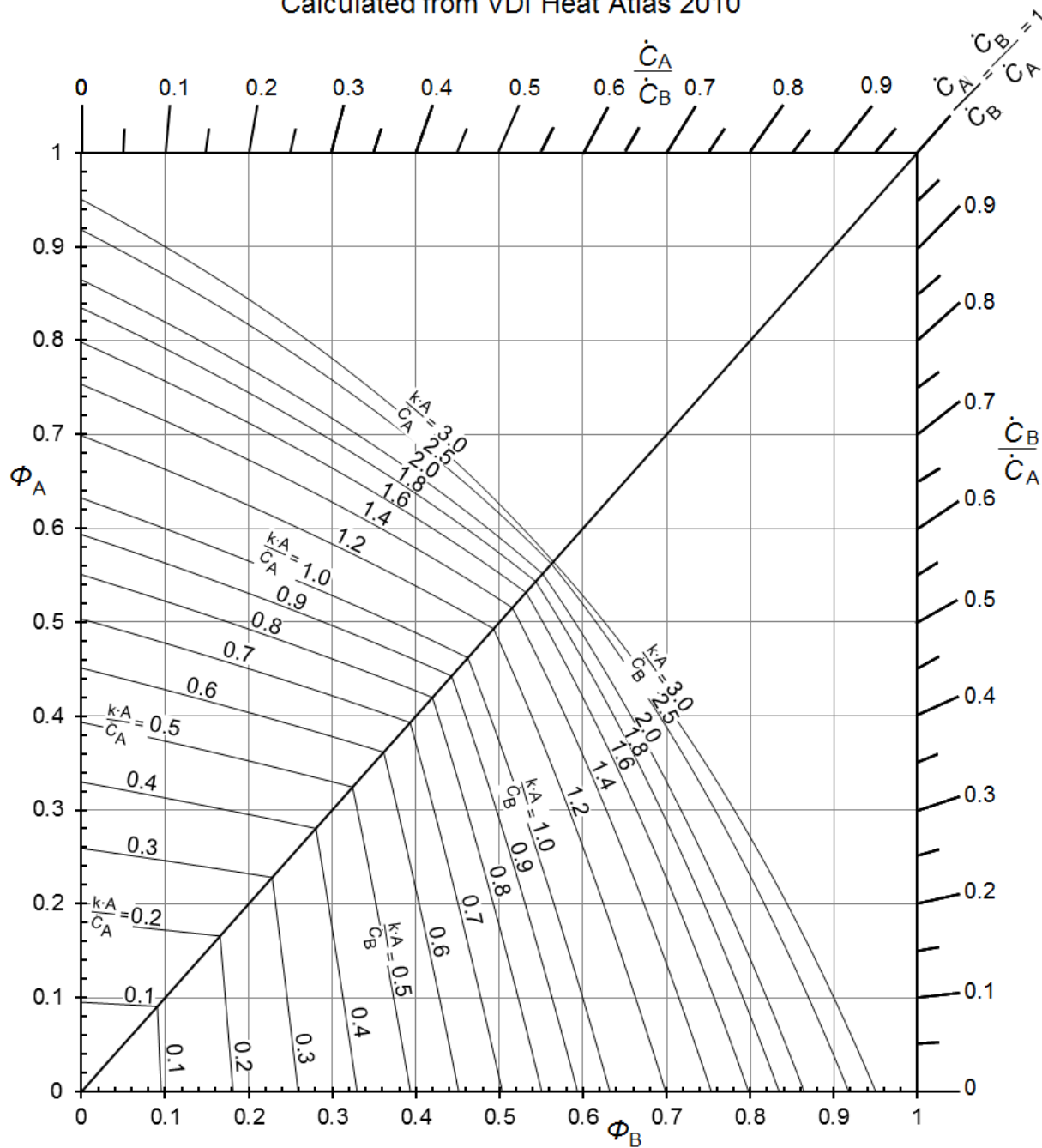


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Figure 5.4: Cross-flow with one tube row, laterally mixed on one side - ITYPE 4

Cross-flow, laterally mixed on both sides Calculated from VDI Heat Atlas 2010

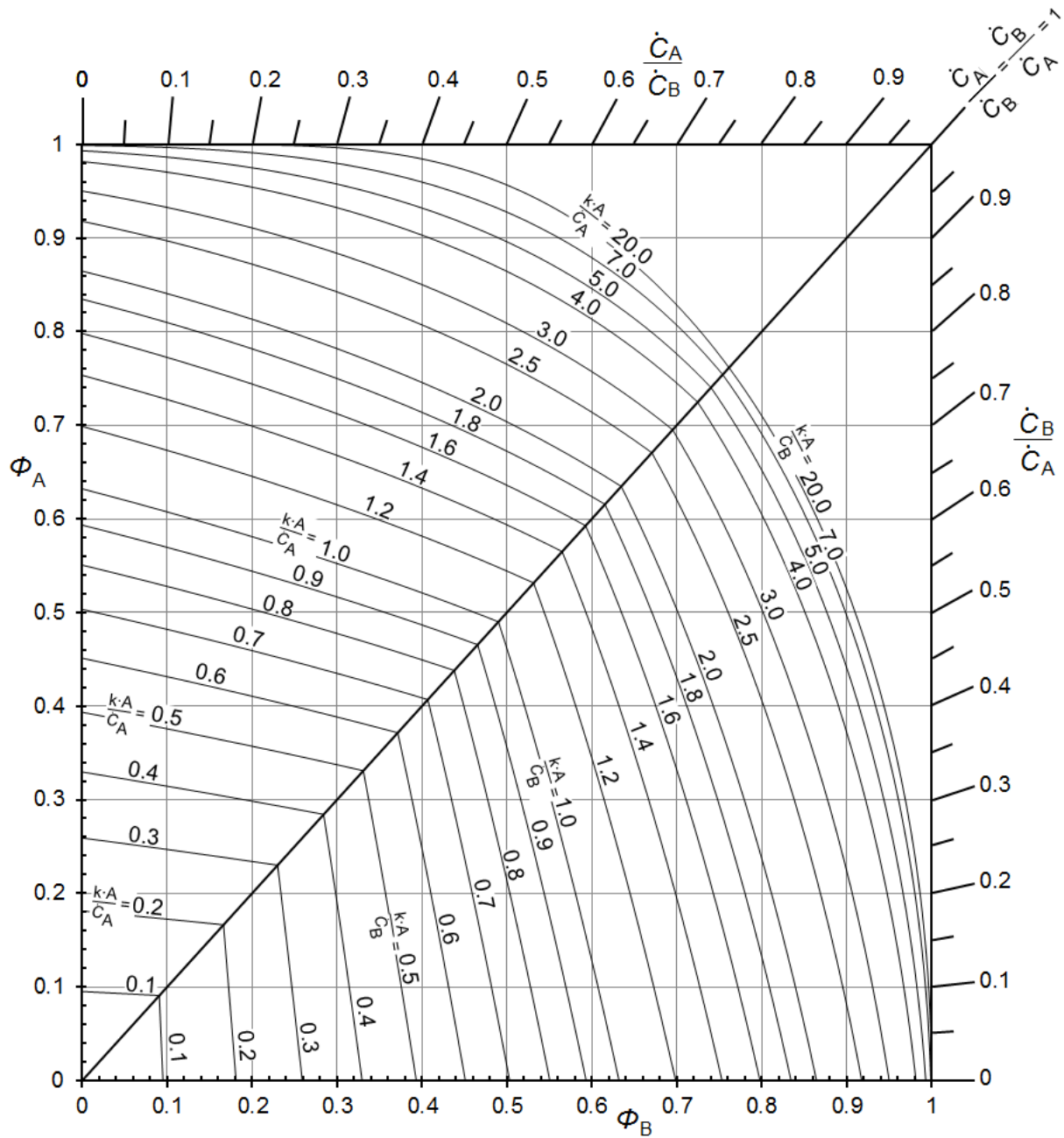


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Figure 5.5: Cross-flow, laterally mixed on both sides - I-TYPE 5

Counterdirected countercurrent cross-flow with
two tube rows and two passes
Calculated from VDI Heat Atlas 2010

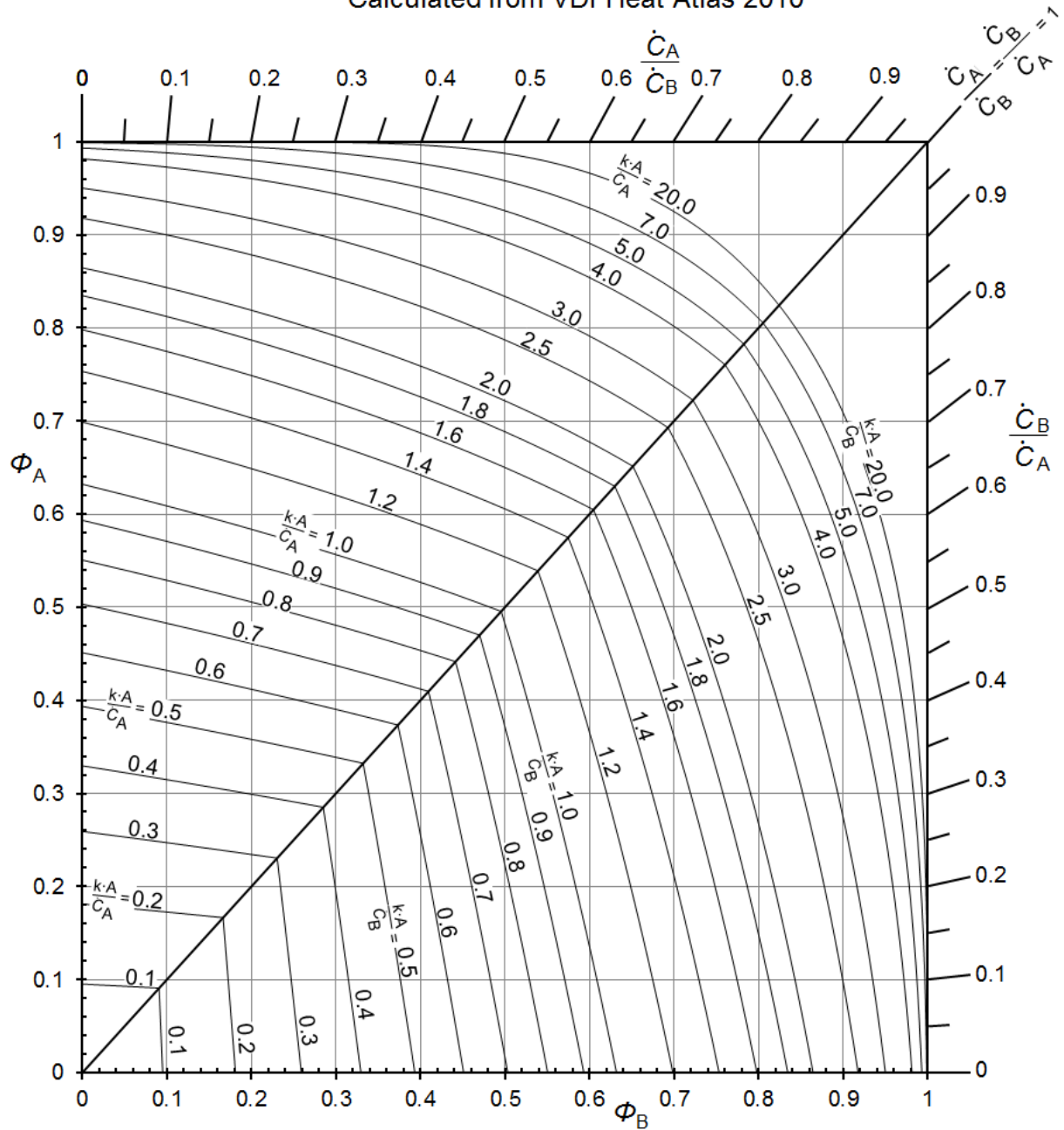


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Figure 5.6: Counterdirected countercurrent cross-flow with two tube rows and two passes - ITYPE 6

Counterdirected countercurrent cross-flow with
three tube rows and three passes
Calculated from VDI Heat Atlas 2010



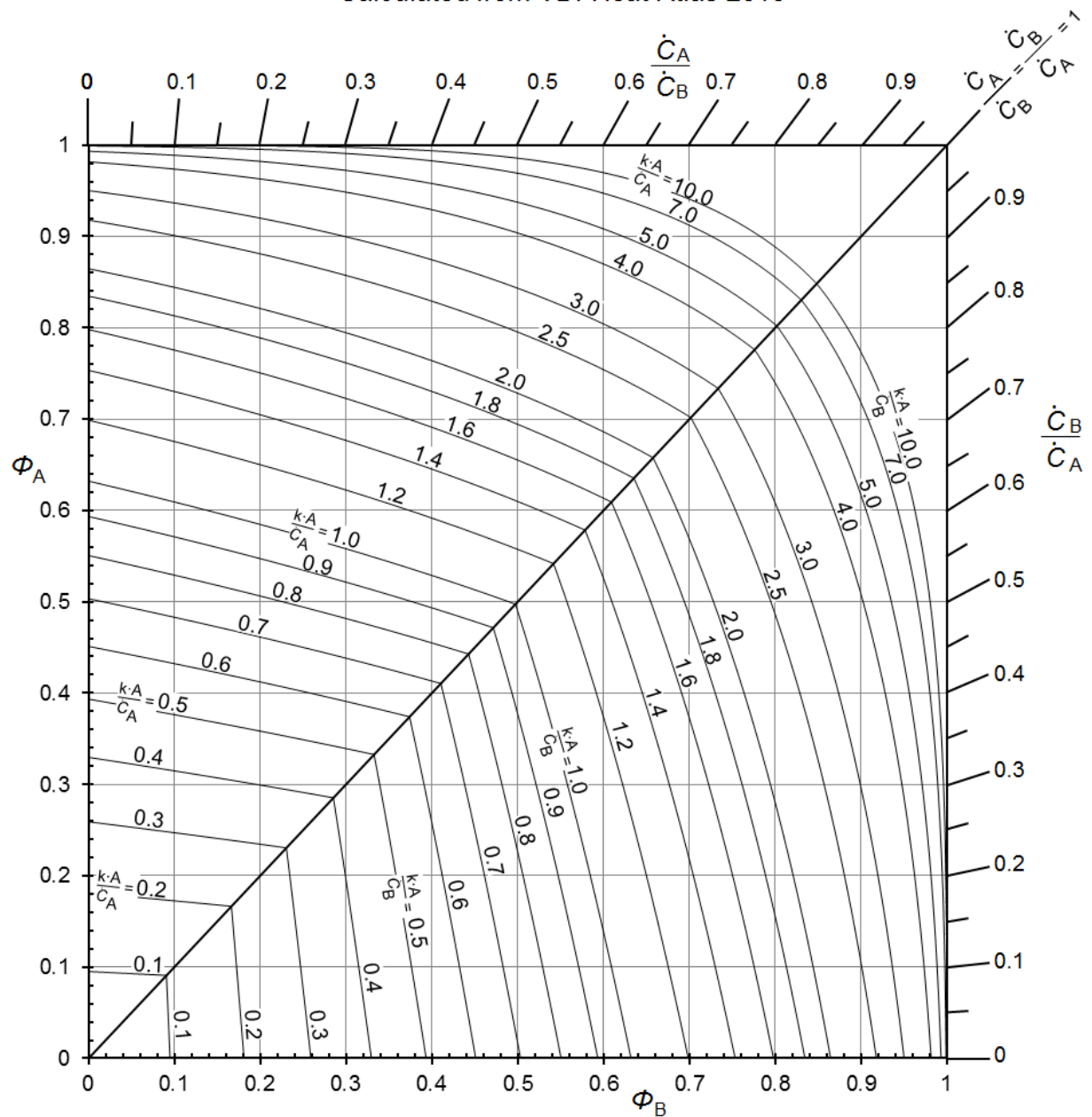
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Figure 5.7: Counterdirected countercurrent cross-flow with three tube rows and three passes - ITYPE 7

Counterdirected countercurrent cross-flow with four tube rows and four passes

Calculated from VDI Heat Atlas 2010

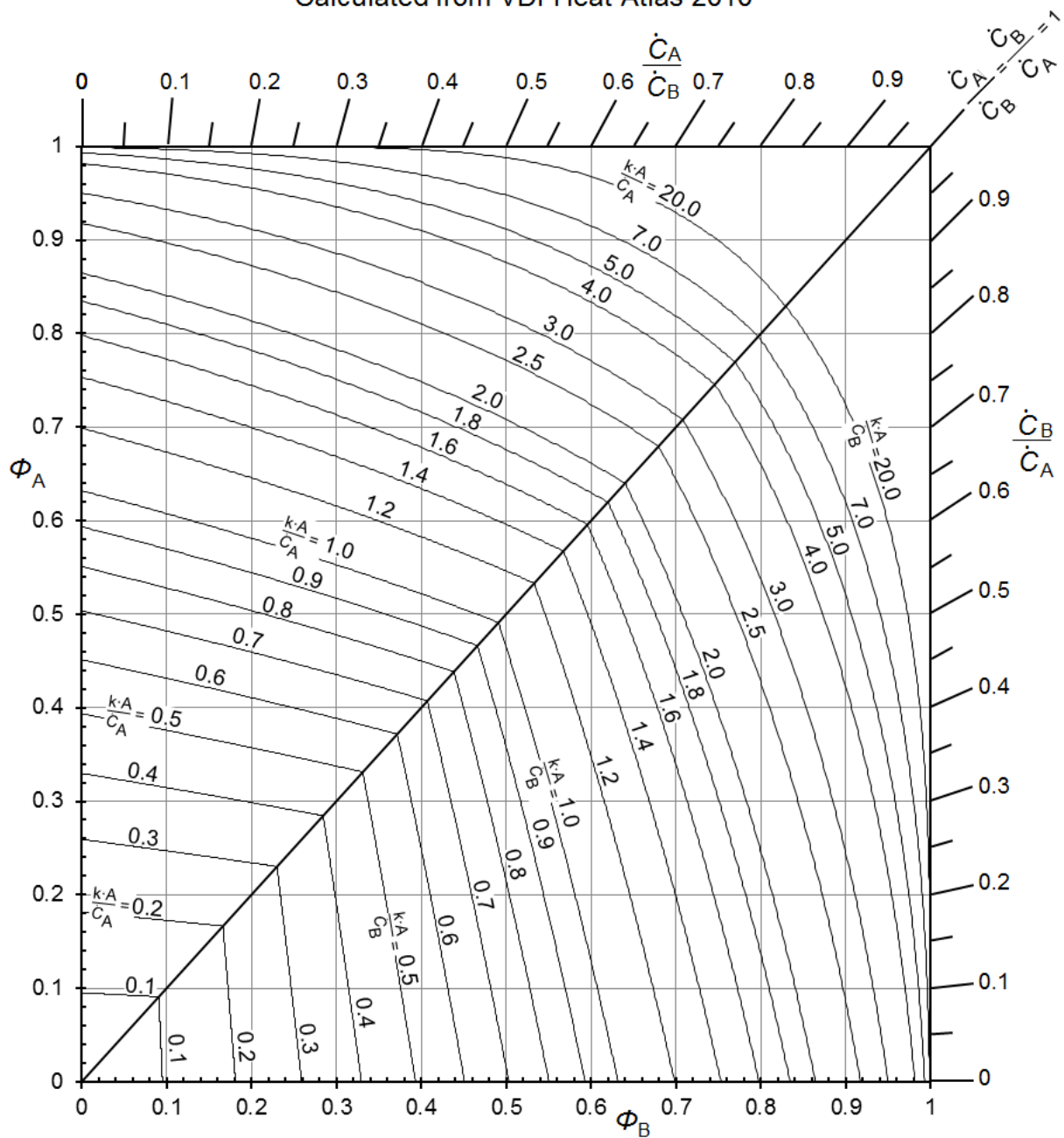


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Figure 5.8: Counterdirected countercurrent cross-flow with four tube rows and four passes - ITYPE 8

Counterdirected countercurrent cross-flow
with four tube rows and two passes
Calculated from VDI Heat Atlas 2010



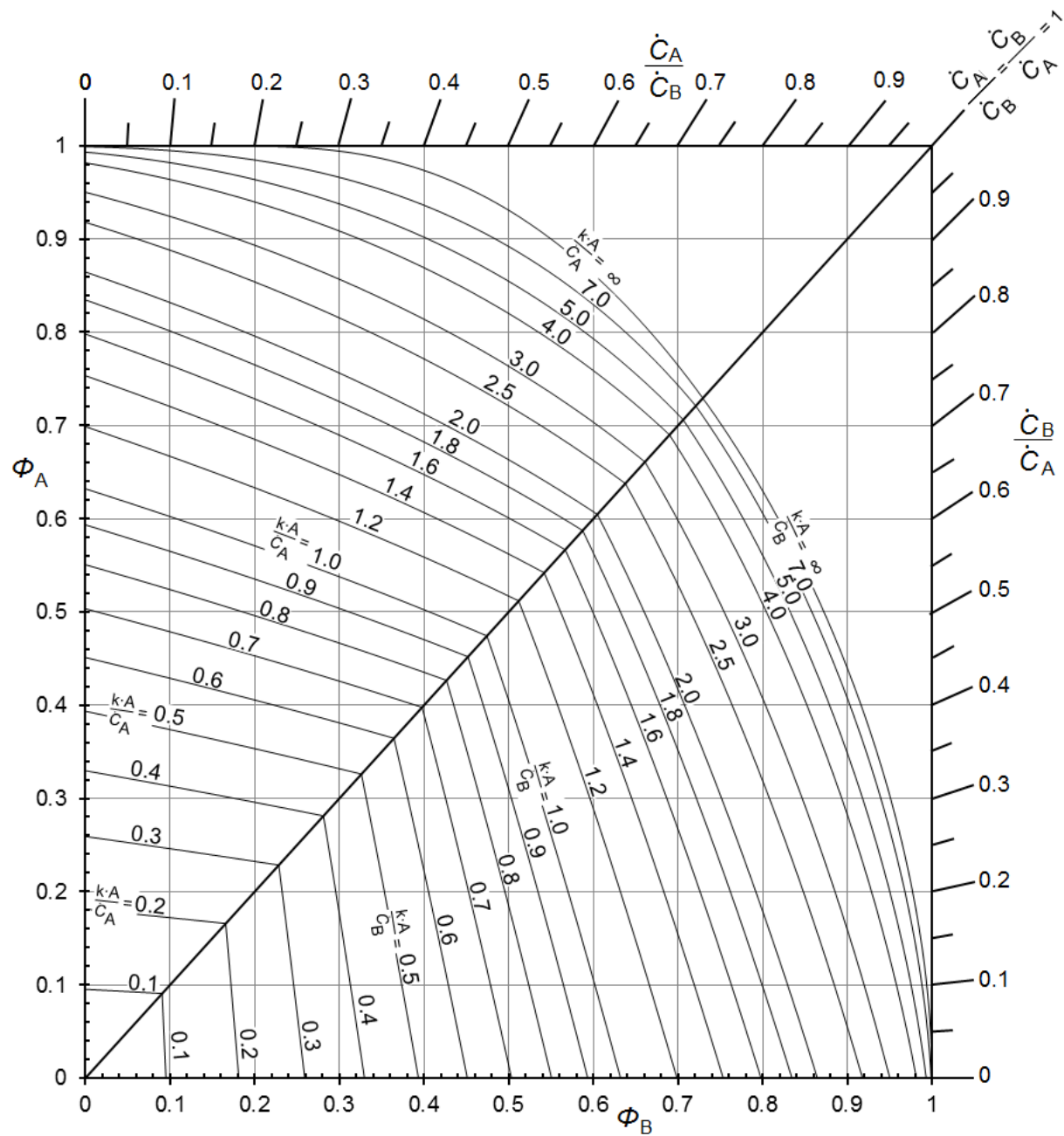
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Figure 5.9: Countercurrent-cross flow with four tube rows and two passes - ITYPE 9

Cross-flow with two tube rows and one pass

Calculated from VDI Heat Atlas 2010



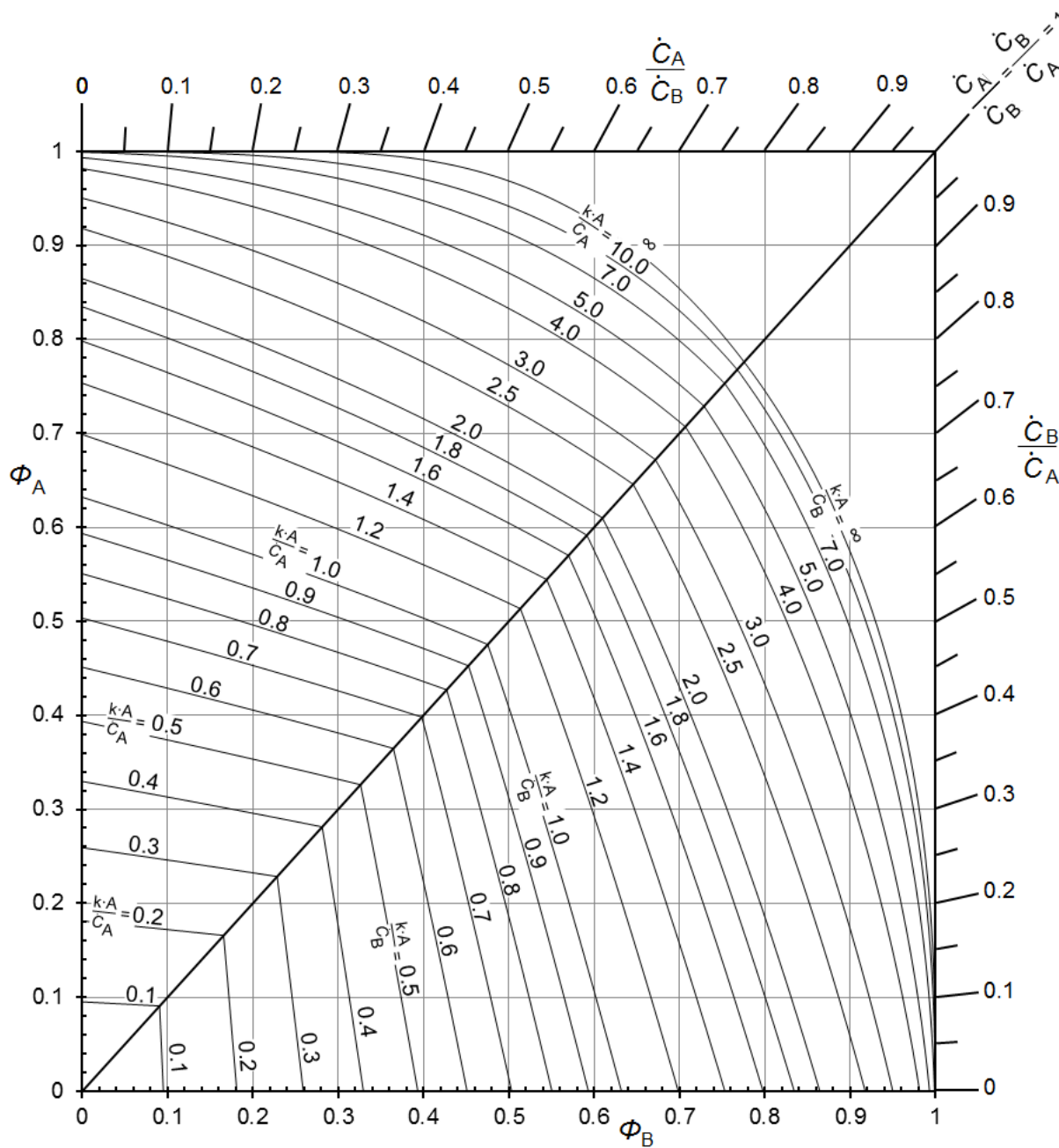
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Figure 5.10: Cross-flow with two tube rows and one pass - I-TYPE 10 and NSPEC 2

Cross-flow with three tube rows and one pass

Calculated from VDI Heat Atlas 2010



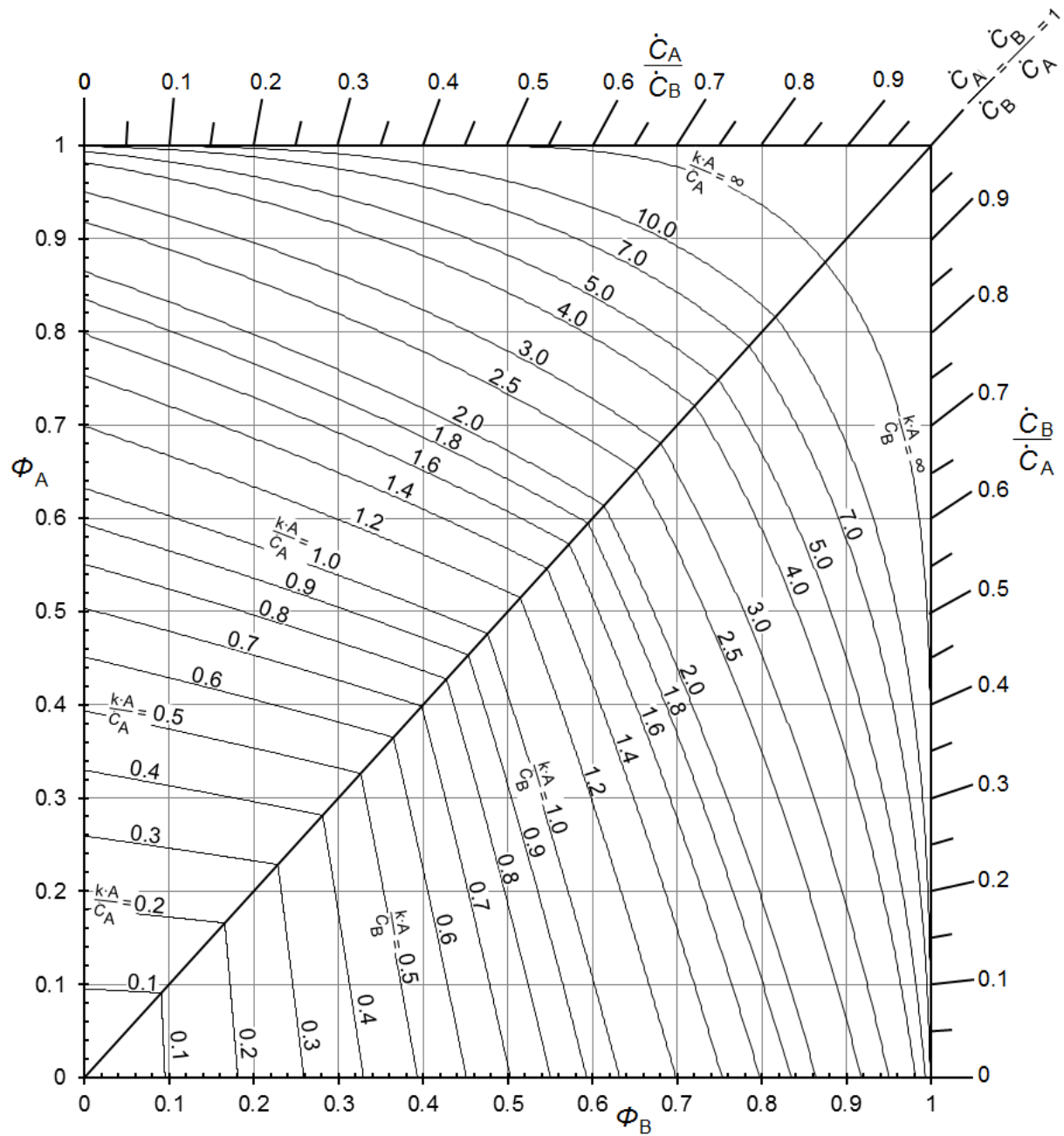
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Figure 5.11: Cross-flow with three tube rows and one pass - ITYPE 10 and NSPEC 3

Cross-flow with ten tube rows and one pass

Calculated from VDI Heat Atlas 2010



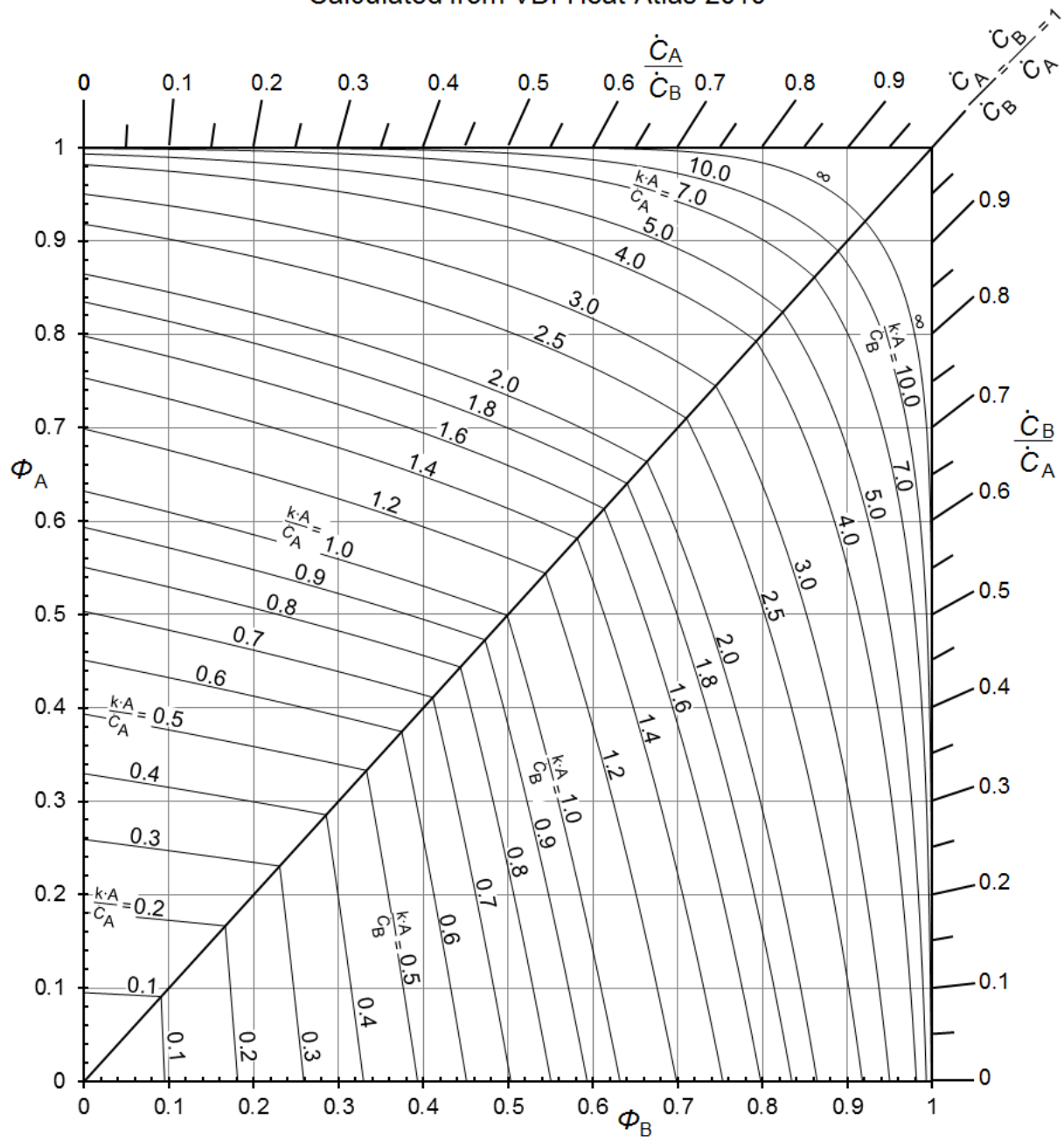
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Figure 5.12: Cross-flow with ten tube rows and one pass - IYPE 10 and NSPEC 10

Codirected countercurrent cross-flow with six tube rows and six passes

Calculated from VDI Heat Atlas 2010



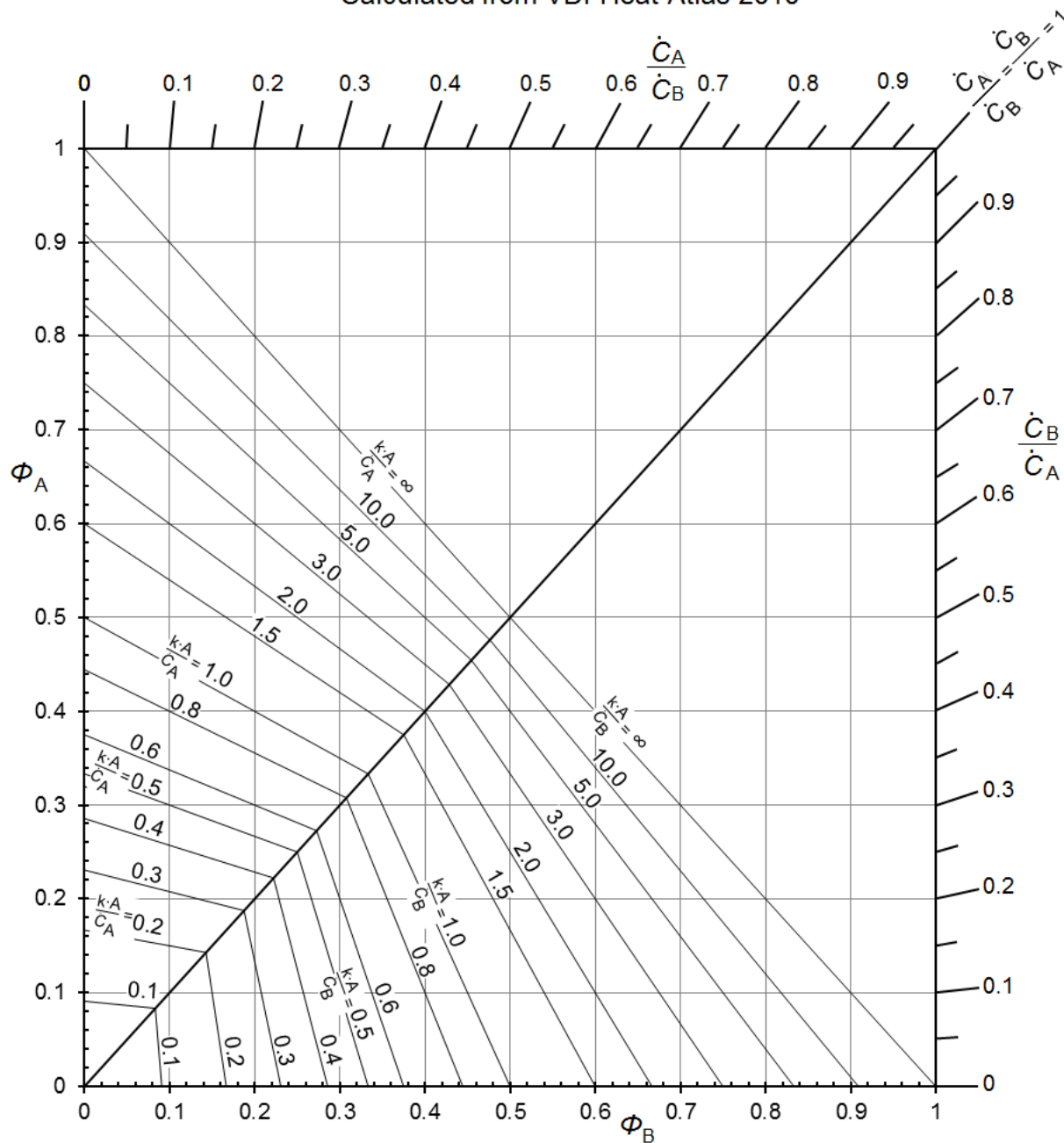
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Figure 5.13: Codirected countercurrent cross-flow with six tube rows and six passes - ITYPE 11 and NSPEC 6

Two-sided stirred tank

Calculated from VDI Heat Atlas 2010



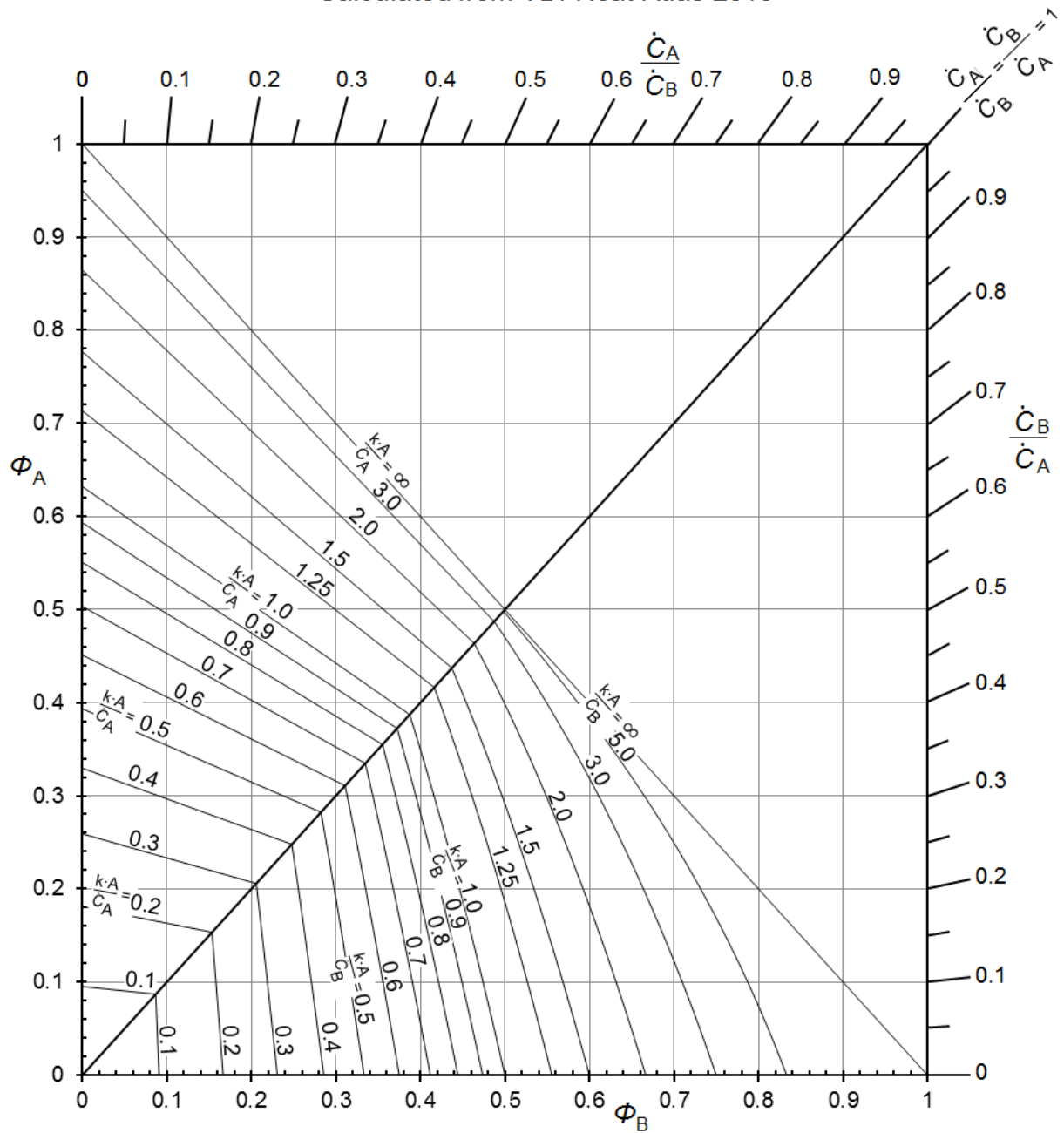
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Figure 5.14: Two-sided stirred tank - ITYPE 12

One-sided stirred tank

Calculated from VDI Heat Atlas 2010



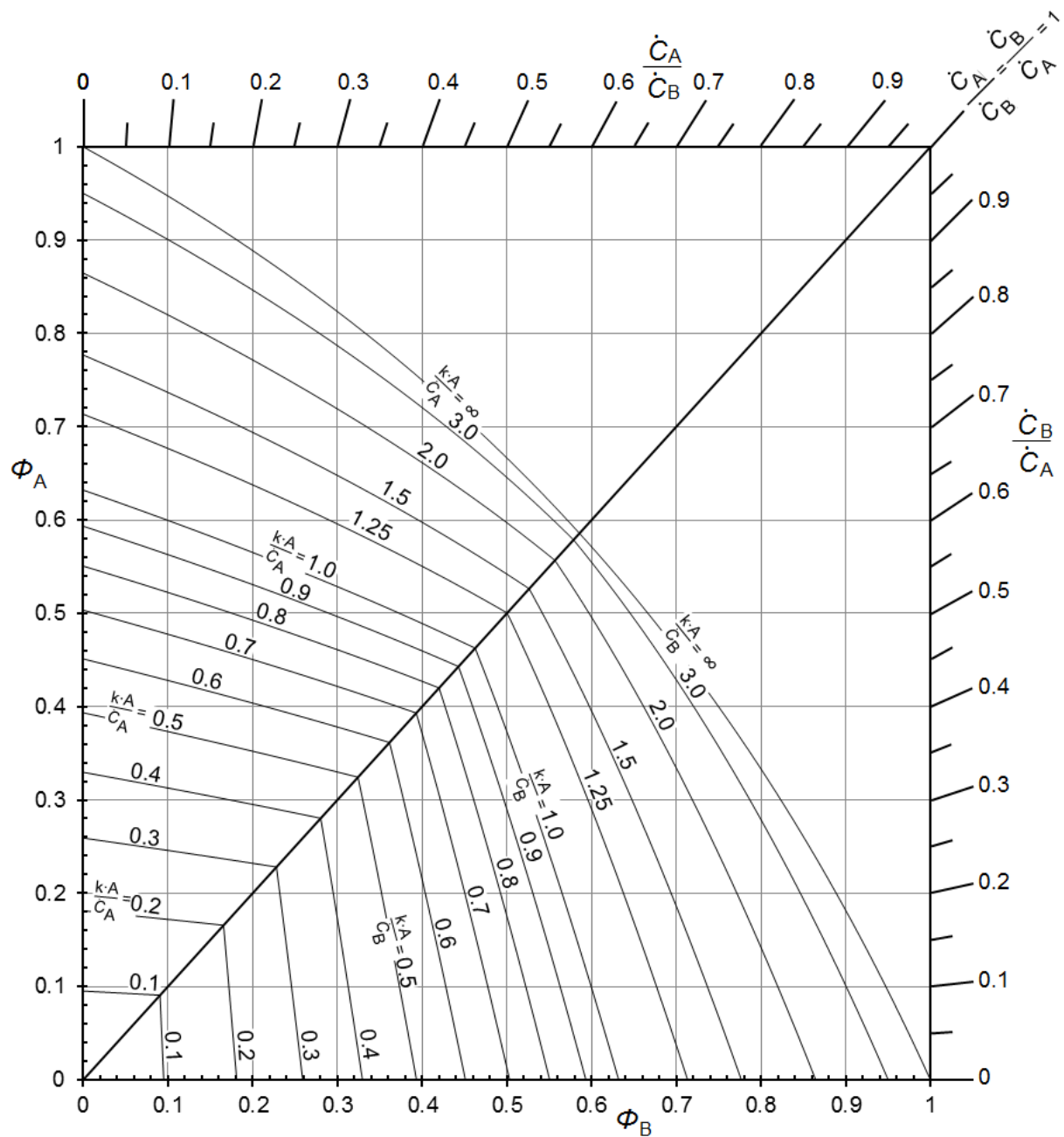
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Figure 5.15: One-sided stirred tank - I-TYPE 13

One shell-side and two tube-side passes

Calculated from VDI Heat Atlas 2010



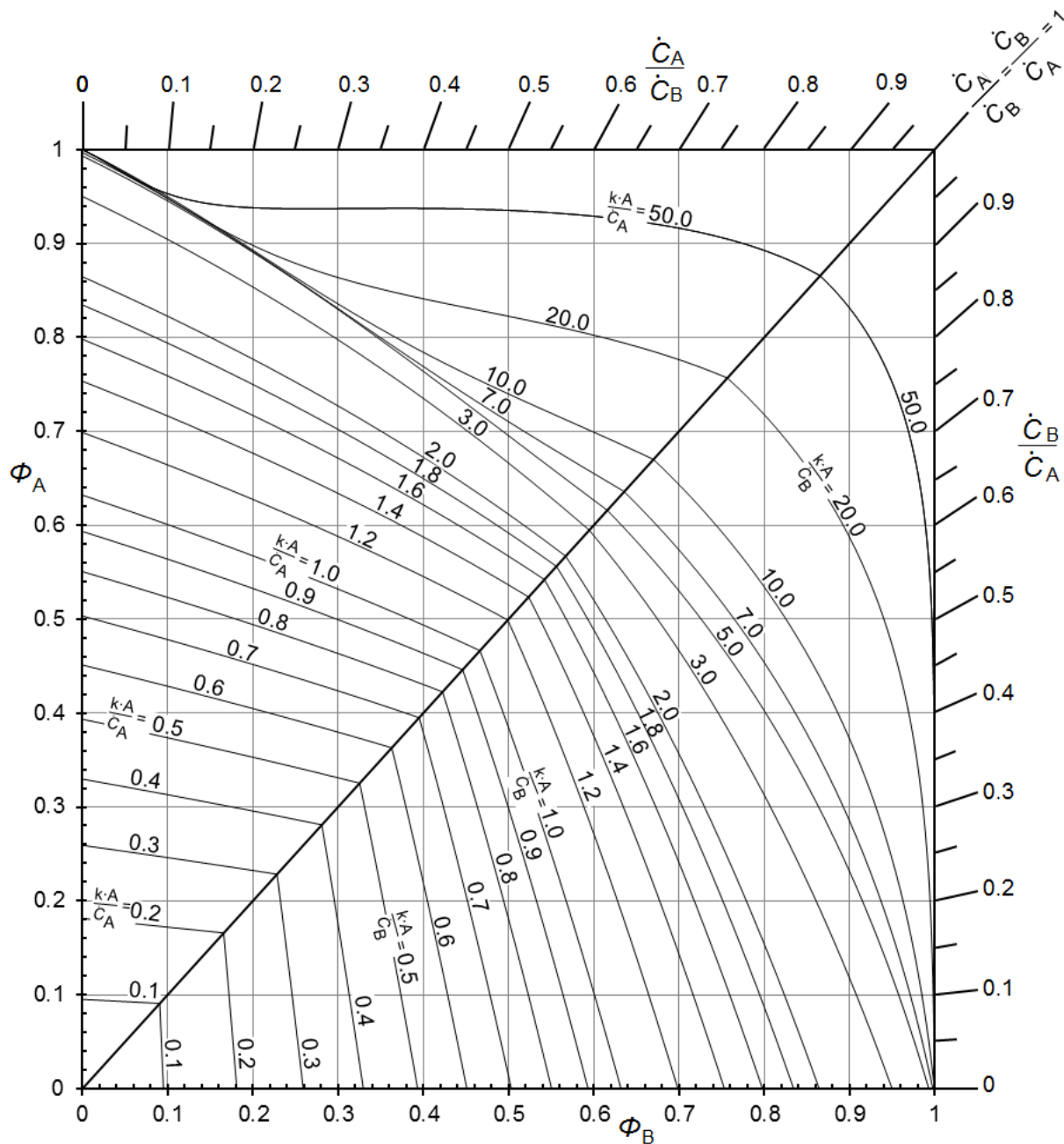
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Figure 5.16: One shell-side and two tube-side passes - ITYPE 14

One shell-side and three tube-side passes, two countercurrent

Calculated from VDI Heat Atlas 2010



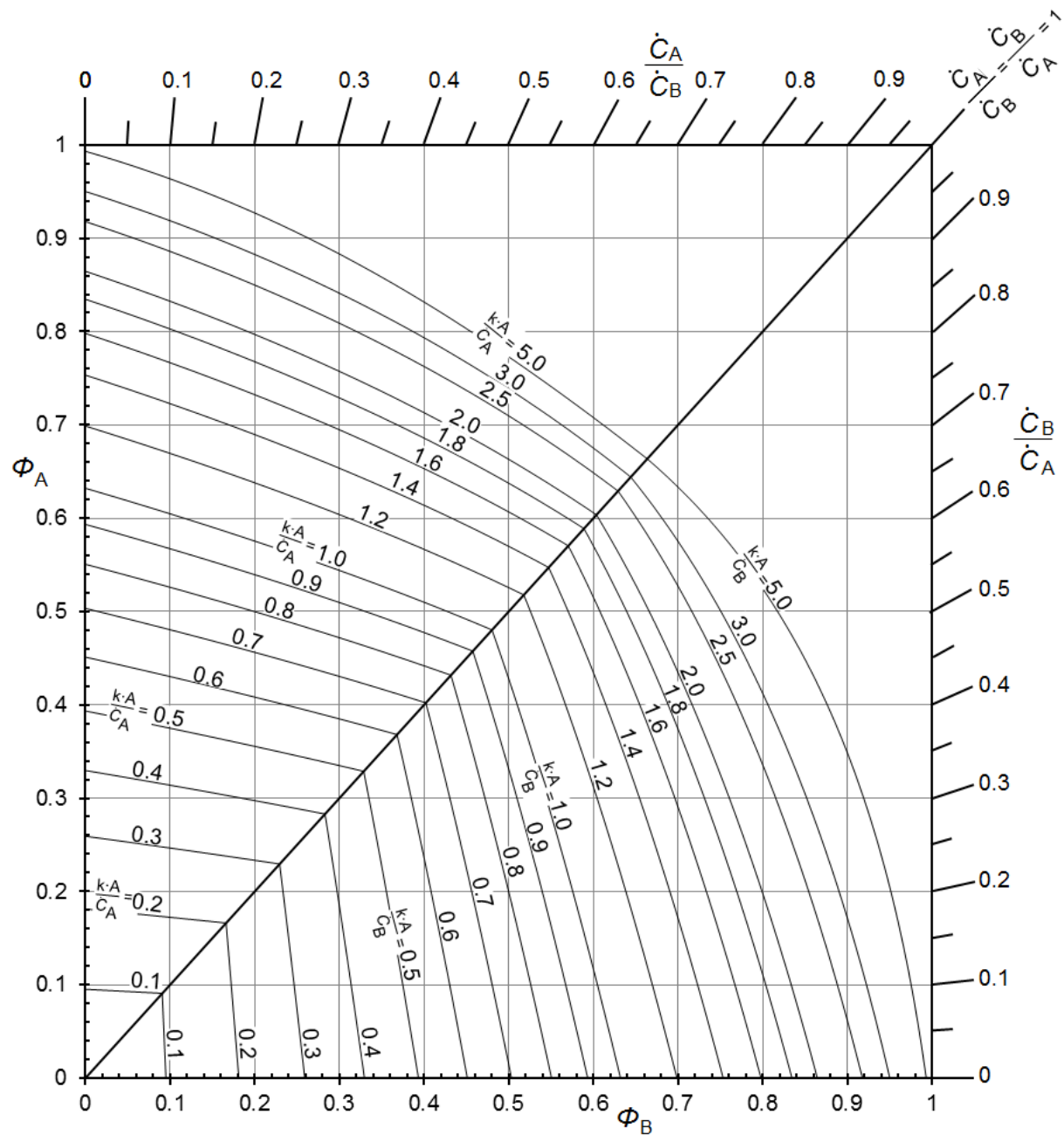
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Figure 5.17: One shell-side and three tube-side passes, two countercurrent - ITYPE 15

One shell-side and two tube-side passes, both countercurrent

Calculated from VDI Heat Atlas 2010

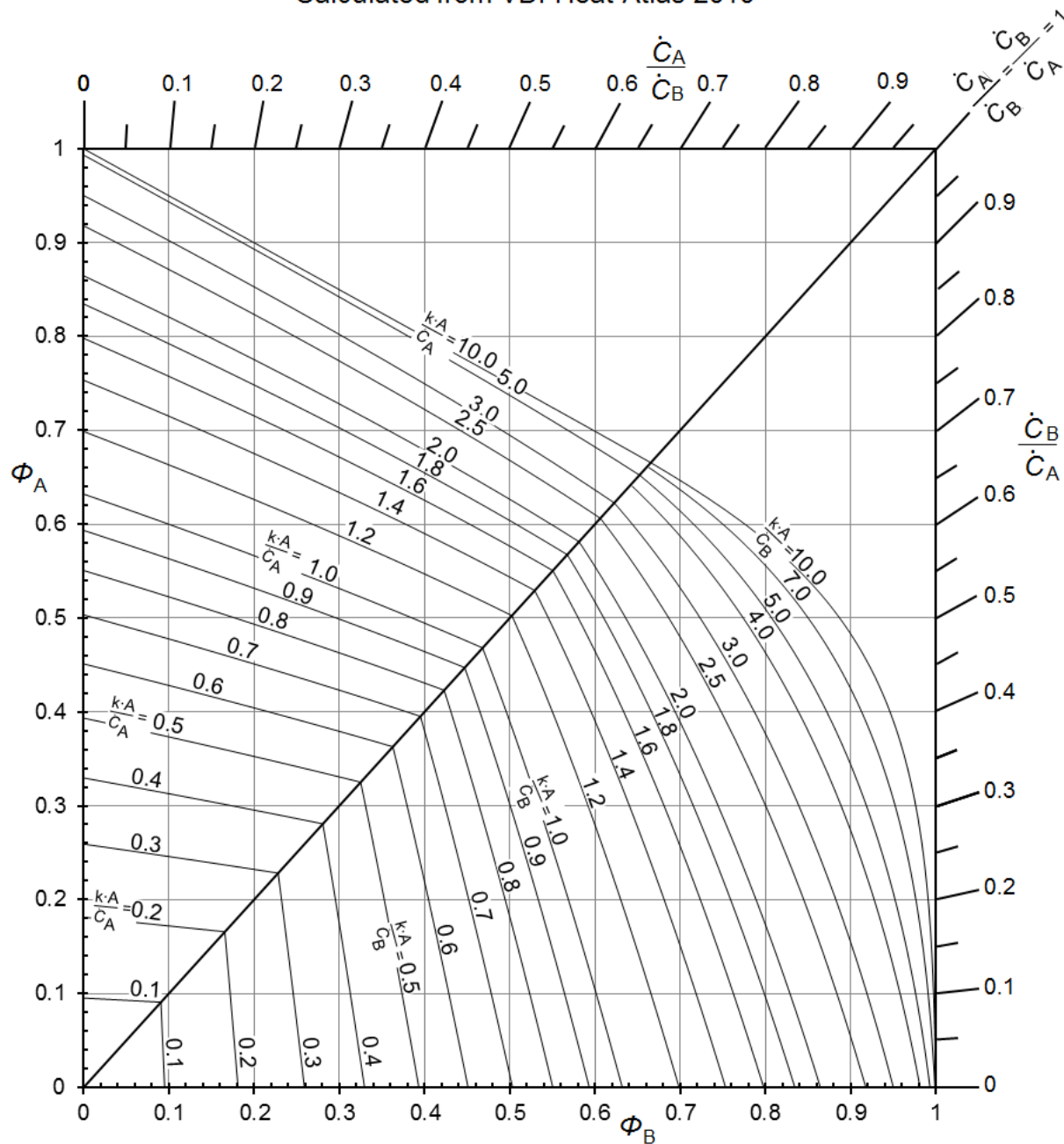


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Figure 5.18: One shell-side and two tube-side passes, both countercurrent - I-TYPE 16

Divided flow with one shellside and one tube-side pass Calculated from VDI Heat Atlas 2010



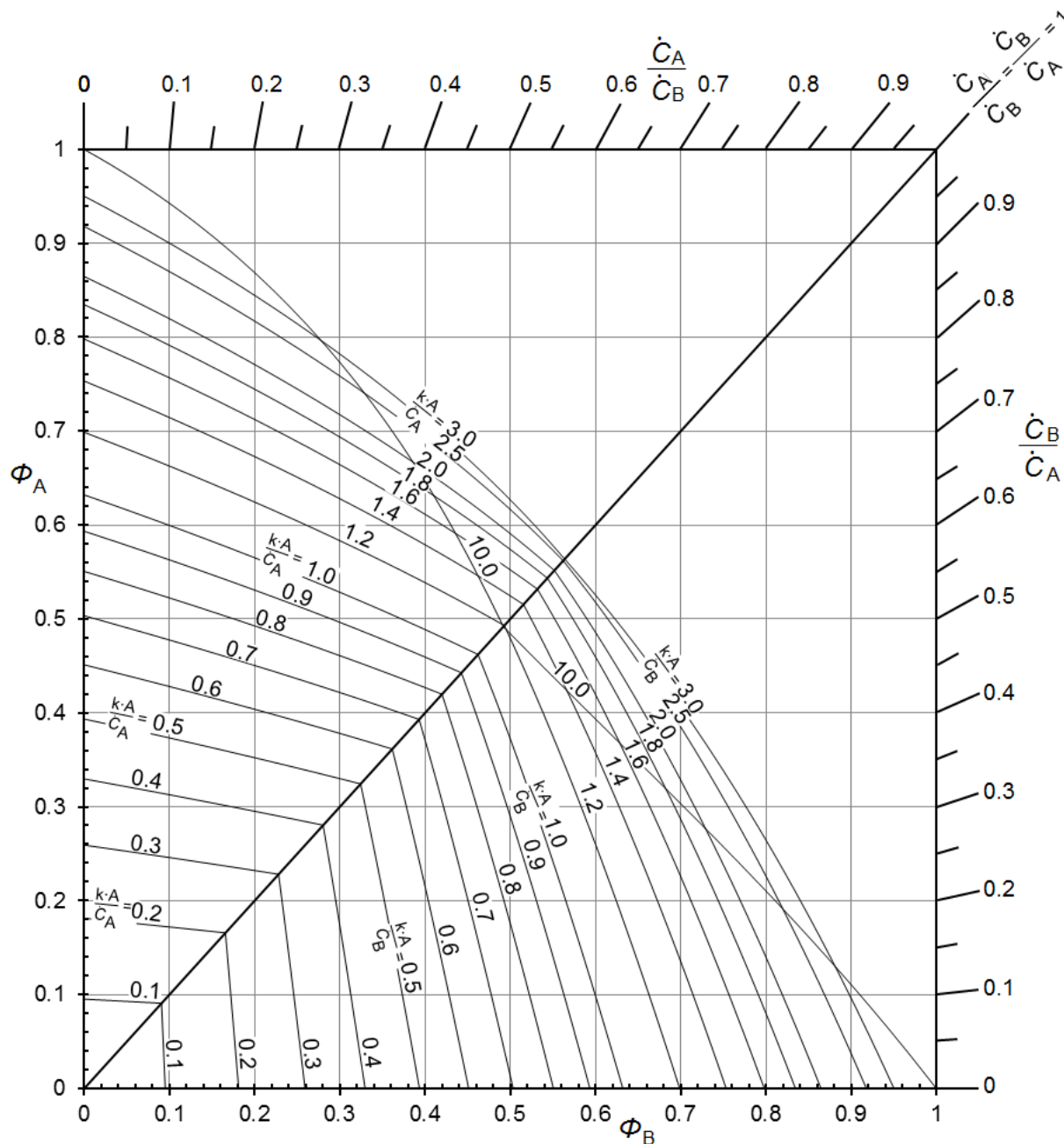
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Figure 5.19: Divided flow with one shellside and one tube-side pass - ITYPE 17

Divided flow with one shell-side and two tube-side passes

Calculated from VDI Heat Atlas 2010



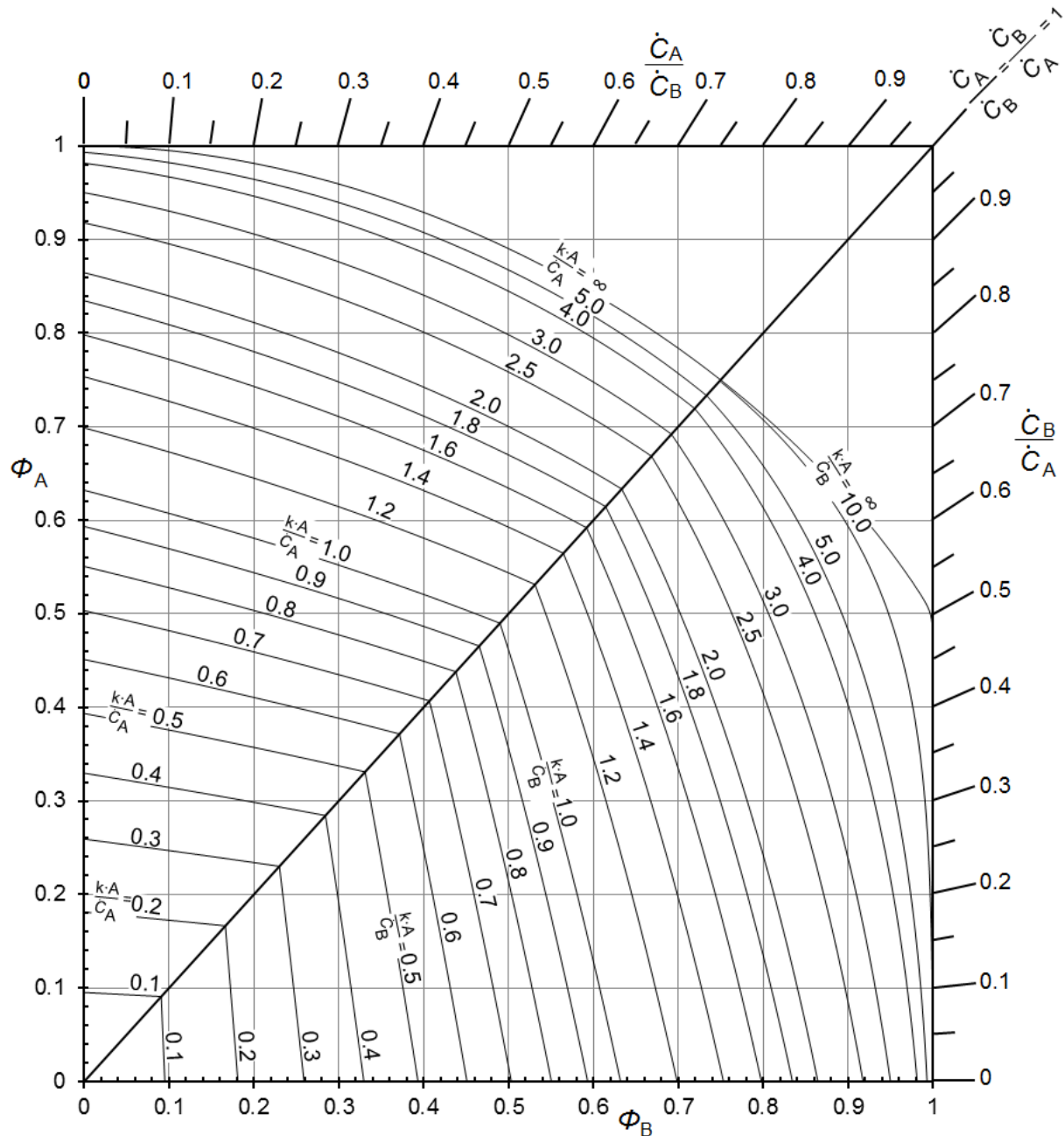
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Figure 5.20: Divided flow with one shell-side and two tube-side passes - ITYPE 18

Split flow with longitudinal baffle and two shell- side
and two tube-side passes (tube-side outlet and
shellside inlet at the same side)

Calculated from VDI Heat Atlas 2010



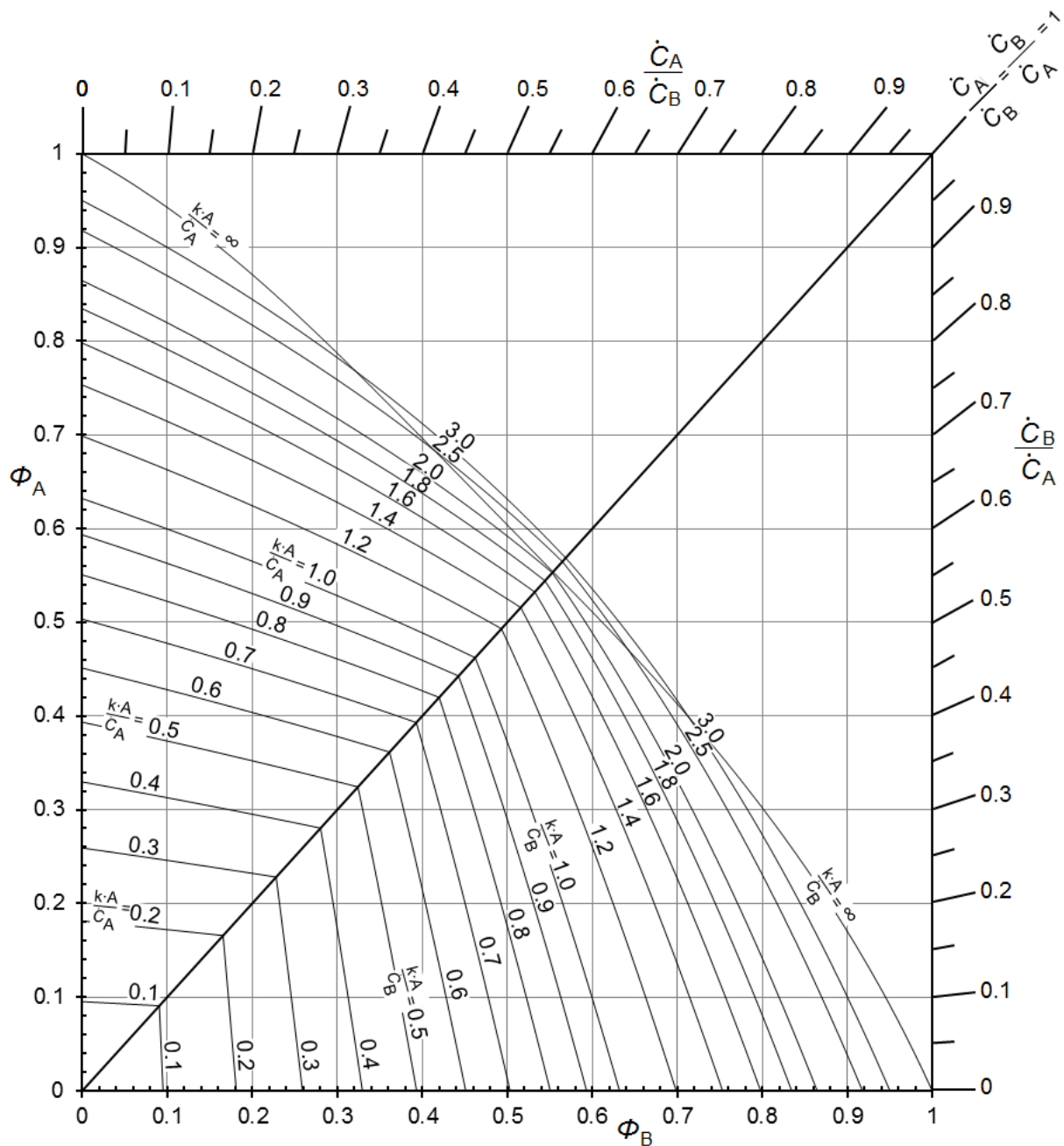
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Figure 5.21: Split flow with longitudinal baffle and two shell-side and two tube-side passes (tube-side outlet and shell-side inlet on the same side) - ITYPE 19

One shell-side and four tube-side passes

Calculated from VDI Heat Atlas 2010



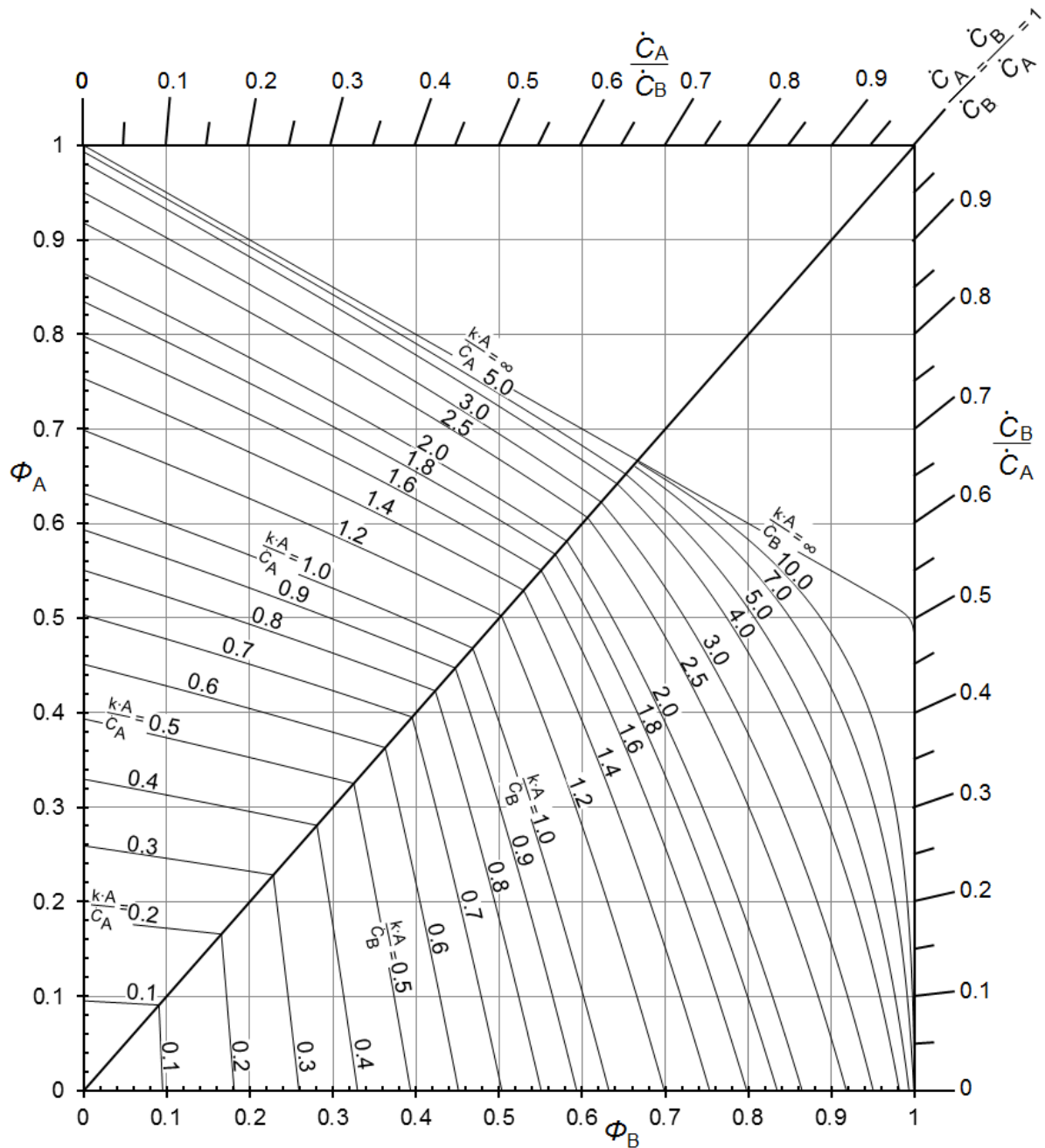
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Figure 5.22: One shell-side and four tube-side passes - ITYPE 20 and NSPEC 2

One pass for stream 1 and two passes for stream 2

Calculated from VDI Heat Atlas 2010

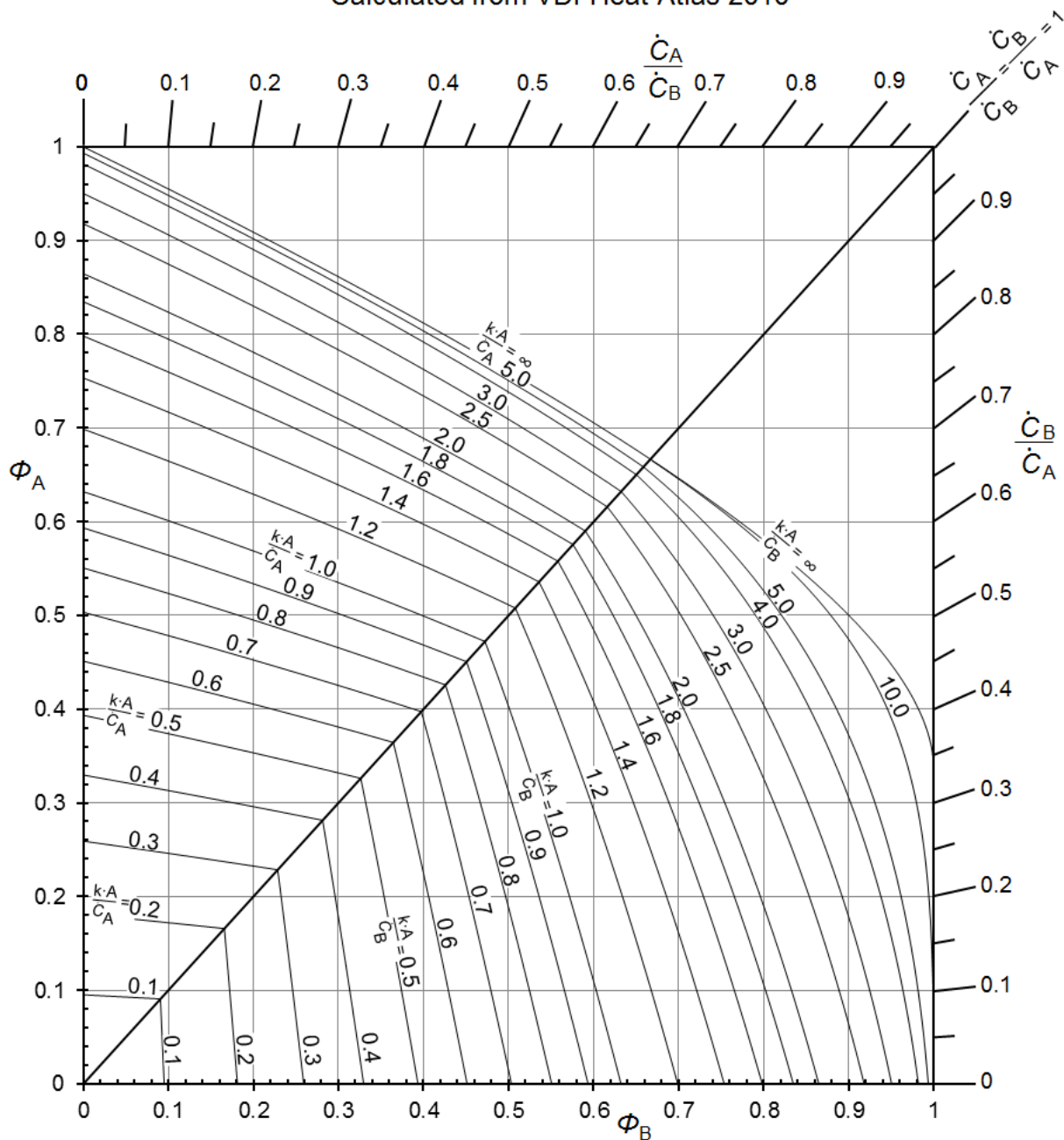


Prepared by Guido Keuchel
 Bearbeitet von Dipl.-Ing. (FH) G. Keuchel

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 Dr. Ines Stoecker
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Figure 5.23: One pass for stream 1 and two passes for stream 2 - ITYPE 21

One pass for stream 1 and three passes for stream 2,
two in countercurrent
Calculated from VDI Heat Atlas 2010

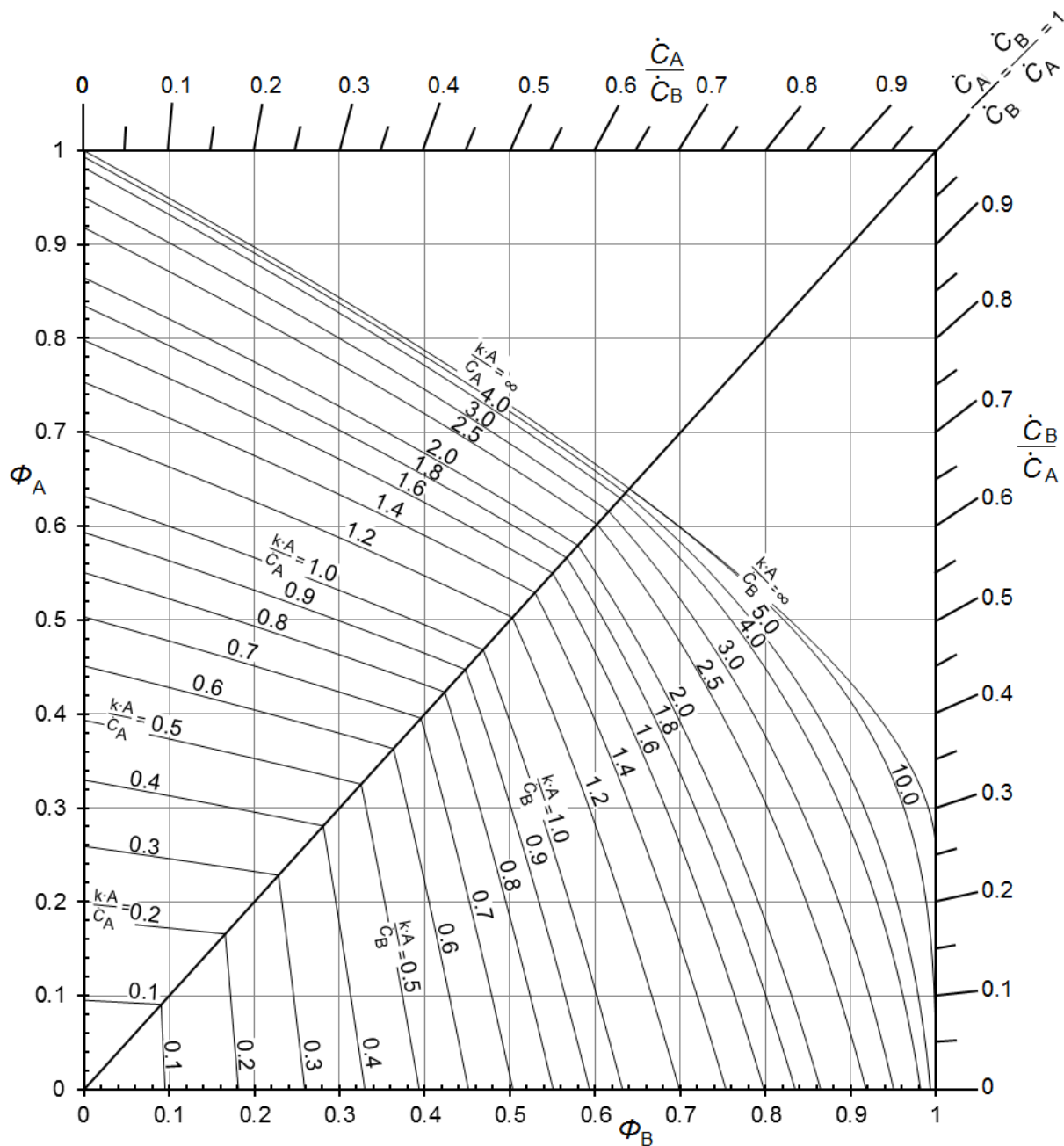


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Figure 5.24: One pass for stream 1 and three passes for stream 2,
two in countercurrent - ITYPE 22

One pass for stream 1 and four passes for stream 2
 Calculated from VDI Heat Atlas 2010

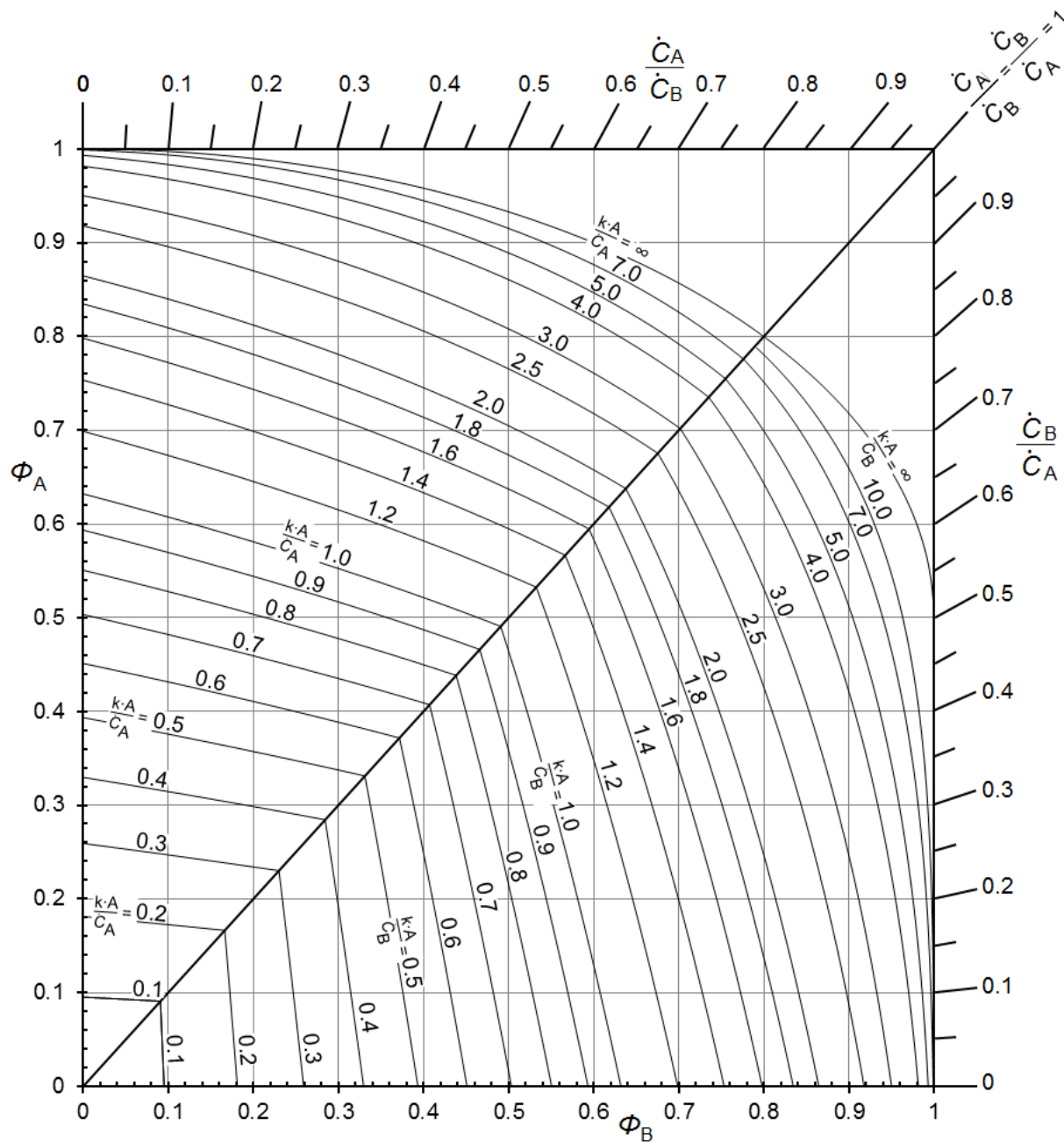


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Figure 5.25: One pass for stream 1 and four passes for stream 2 - ITYPE 23

Two passes for stream 1 and four passes for
stream 2 in overall counterflow
Calculated from VDI Heat Atlas 2010



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Figure 5.26: Two passes for stream 1 and four passes for stream 2
in overall counterflow - ITYPE 24



4. Property Libraries for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

Water and Steam

Library LibIF97

- Industrial Formulation IAPWS-IF97 (Revision 2007)
- Supplementary Standards
 - IAPWS-IF97-S01
 - IAPWS-IF97-S03rev
 - IAPWS-IF97-S04
 - IAPWS-IF97-S05
- IAPWS Revised Advisory Note No. 3 on Thermodynamic Derivatives (2008)

Humid Combustion Gas Mixtures

Library LibHuGas

Model: Ideal mixture of the real fluids:
CO₂ - Span and Wagner O₂ - Schmidt and Wagner
H₂O - IAPWS-95 Ar - Tegeler et al.
N₂ - Span et al.
and of the ideal gases:
SO₂, CO, Ne (Scientific Formulation of Bückner et al.)
Consideration of:
Dissociation from VDI 4670 and Poynting effect

Humid Air

Library LibHuAir

Model: Ideal mixture of the real fluids:
• Dry air from Lemmon et al.
• Steam, water and ice from IAPWS-IF97 and IAPWS-06
Consideration of:
• Condensation and freezing of steam
• Dissociation from the VDI 4670
• Poynting effect from ASHRAE RP-1485

Carbon Dioxide Including Dry Ice

Library LibCO2

Formulation of Span and Wagner (1996)

Seawater

Library LibSeaWa

IAPWS Industrial Formulation 2013

Ice

Library LibICE

Ice from IAPWS-06, Melting and sublimation pressures from IAPWS-08, Water from IAPWS-IF97, Steam from IAPWS-95 and -IF97

Ideal Gas Mixtures

Library LibIdGasMix

Model: Ideal mixture of the ideal gases:
Ar NO He Propylene
Ne H₂O F₂ Propane
N₂ SO₂ NH₃ Iso-Butane
O₂ H₂ Methane n-Butane
CO H₂S Ethane Benzene
CO₂ OH Ethylene Methanol
Air

Consideration of:
• Dissociation from the VDI Guideline 4670

Library LibIDGAS

Model: Ideal gas mixture from VDI Guideline 4670

Consideration of:
• Dissociation from the VDI Guideline 4670

Humid Air

Library ASHRAE LibHuAirProp

Model: Virial Equation from ASHRAE Report RP-1485 for real mixture of the real fluids:
- Dry air
- Steam

Consideration of:
• Enhancement of the partial saturation pressure of water vapor at elevated total pressures
www.ashrae.org/bookstore

Dry Air Including Liquid Air

Library LibRealAir

Formulation of Lemmon et al. (2000)

Refrigerants

Ammonia

Library LibNH3

Formulation of Tillner-Roth et al. (1993)

R134a

Library LibR134a

Formulation of Tillner-Roth and Baehr (1994)

Iso-Butane

Library LibButane_Iso

Formulation of Bückner and Wagner (2006)

n-Butane

Library LibButane_n

Formulation of Bückner and Wagner (2006)

Mixtures for Absorption Processes

Ammonia/Water Mixtures

Library LibAmWa

IAPWS Guideline 2001 of Tillner-Roth and Friend (1998)
Helmholtz energy equation for the mixing term (also useable for calculating Kalina Cycle)

Water/Lithium Bromide Mixtures

Library LibWaLi

Formulation of Kim and Infante Ferreira (2004)
Gibbs energy equation for the mixing term

Liquid Coolants

Liquid Secondary Refrigerants

Library LibSecRef

Liquid solutions of water with
C₂H₆O₂ Ethylene glycol
C₃H₈O₂ Propylene glycol
C₂H₅OH Ethyl alcohol
CH₃OH Methyl alcohol
C₃H₈O₃ Glycerol
K₂CO₃ Potassium carbonate
CaCl₂ Calcium chloride
MgCl₂ Magnesium chloride
NaCl Sodium chloride
C₂H₃KO₂ Potassium acetate
Formulation of the International Institute of Refrigeration (1997)

Ethanol**Library LibC2H5OH**

Formulation of Schroeder
(2012)

Methanol**Library LibCH3OH**

Formulation of
de Reuck and Craven (1993)

Propane**Library LibPropane**

Formulation of
Lemmon et al. (2009)

Siloxanes as ORC Working Fluids

Octamethylcyclotetrasiloxane $C_8H_{24}O_4Si_4$ **Library LibD4**

Decamethylcyclopentasiloxane $C_{10}H_{30}O_5Si_5$ **Library LibD5**

Tetradecamethylhexasiloxane $C_{14}H_{42}O_6Si_6$ **Library LibMD4M**

Hexamethyldisiloxane $C_6H_{18}OSi_2$ **Library LibMM**

Formulation of Colonna et al. (2006)

Dodecamethylcyclohexasiloxane $C_{12}H_{36}O_6Si_6$ **Library LibD6**

Decamethyltetrasiloxane $C_{10}H_{30}O_3Si_4$ **Library LibMD2M**

Dodecamethylpentasiloxane $C_{12}H_{36}O_4Si_5$ **Library LibMD3M**

Octamethyltrisiloxane $C_8H_{24}O_2Si_3$ **Library LibMDM**

Formulation of Colonna et al. (2008)

Nitrogen**Library LibN2**

Formulation of
Span et al. (2000)

Hydrogen**Library LibH2**

Formulation of
Leachman et al. (2009)

Helium**Library LibHe**

Formulation of Arp et al. (1998)

Hydrocarbons

Decane $C_{10}H_{22}$ **Library LibC10H22**

Isopentane C_5H_{12} **Library LibC5H12_ISO**

Neopentane C_5H_{12} **Library LibC5H12_NEO**

Isohexane C_6H_{14} **Library LibC6H14**

Toluene C_7H_8 **Library LibC7H8**

Formulation of Lemmon and Span (2006)

Further Fluids

Carbon monoxide **CO** **Library LibCO**

Carbonyl sulfide **COS** **Library LibCOS**

Hydrogen sulfide **H₂S** **Library LibH2S**

Dinitrogen monoxide **N₂O** **Library LibN2O**

Sulfur dioxide **SO₂** **Library LibSO2**

Acetone **C₃H₆O** **Library LibC3H6O**

Formulation of Lemmon and Span (2006)

For more information please contact:

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Phone: +49-3583-61-1846
Fax.: +49-3583-61-1846

The following thermodynamic and transport properties can be calculated^a:**Thermodynamic Properties**

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl number Pr

Backward Functions

- $T, v, s(p, h)$
- $T, v, h(p, s)$
- $p, T, v(h, s)$
- $p, T(v, h)$
- $p, T(v, u)$

Thermodynamic Derivatives

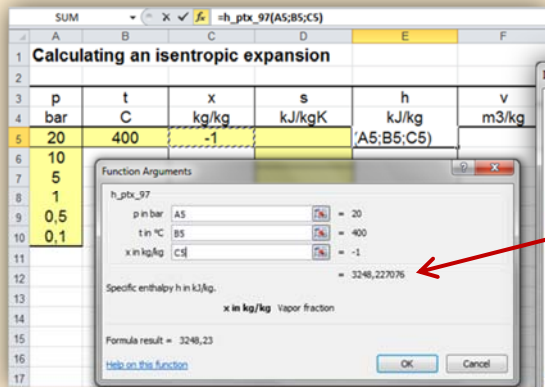
- Partial derivatives can be calculated.

^a Not all of these property functions are available in all property libraries.

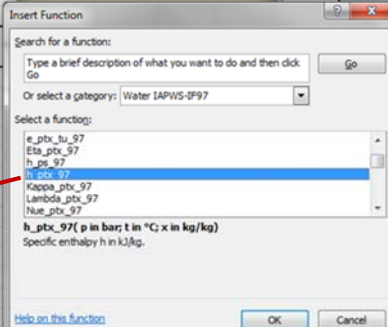


Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

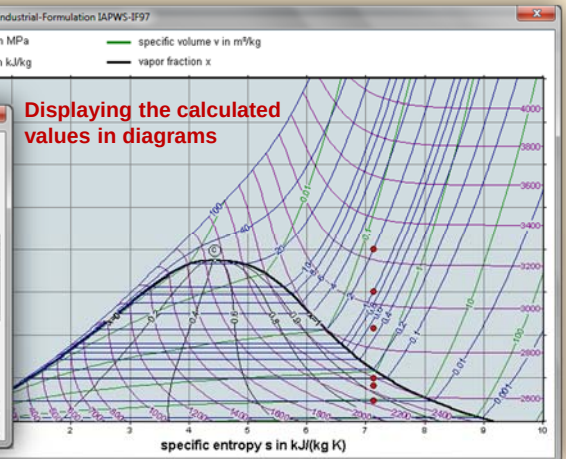
Add-In FluidEXL^{Graphics} for Excel[®]



Choosing a property library and a function



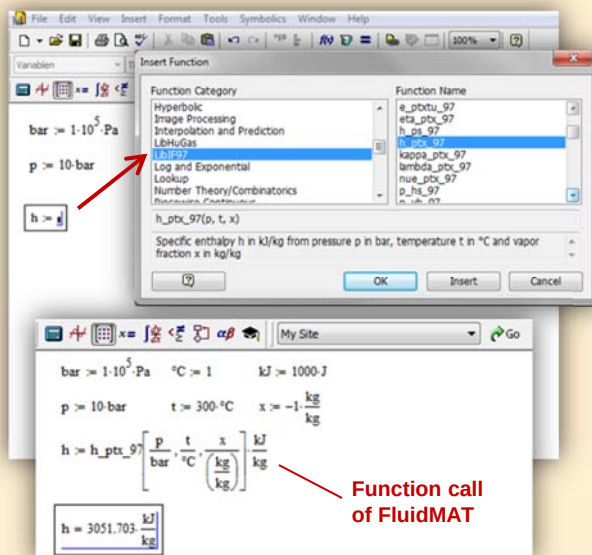
Displaying the calculated values in diagrams



Menu for the input of given property values

Add-In FluidMAT for Mathcad[®]

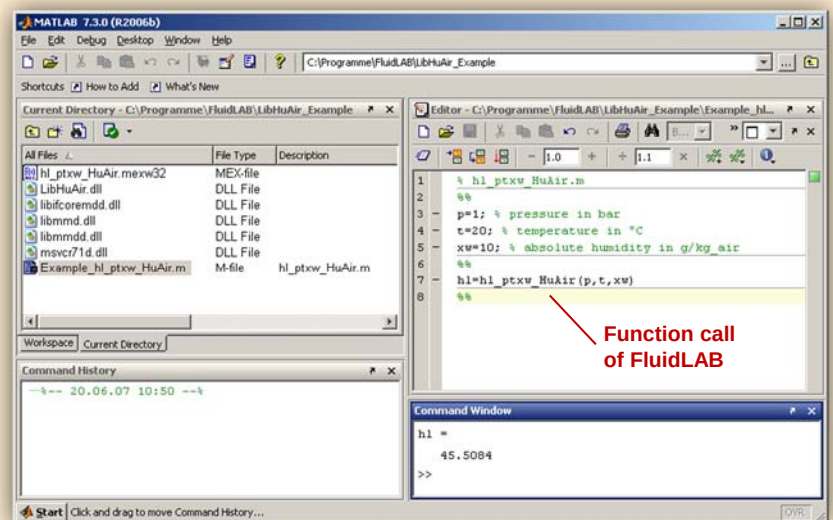
The property libraries can be used in Mathcad[®].



Function call of FluidMAT

Add-In FluidLAB for MATLAB[®]

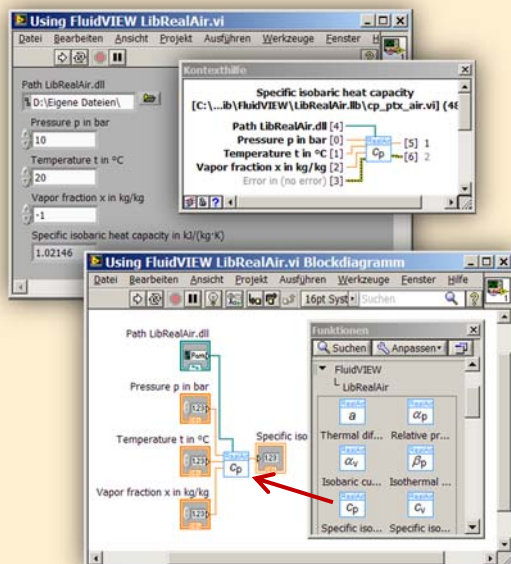
Using the Add-In FluidLAB the property functions can be called in MATLAB[®].



Function call of FluidLAB

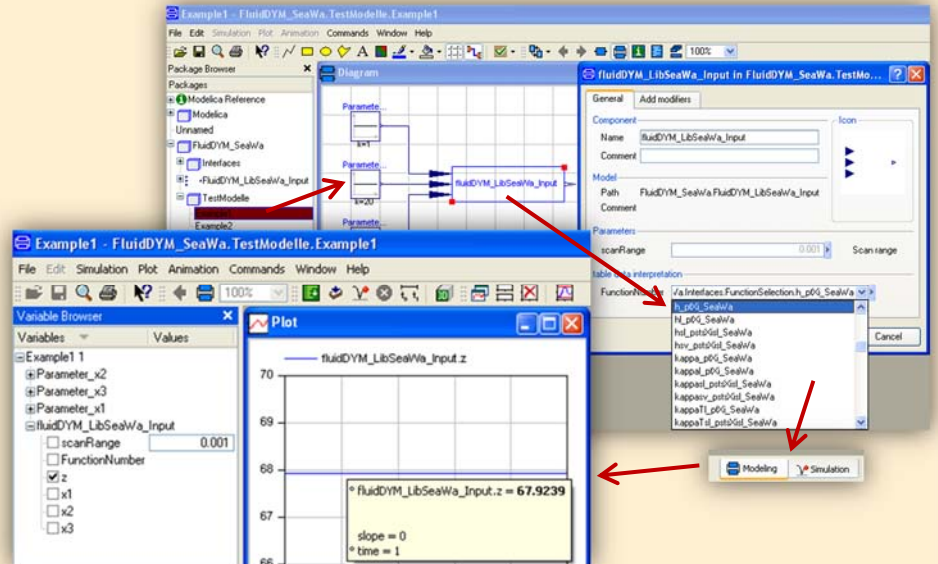
Add-On FluidVIEW for LabVIEW[®]

The property functions can be calculated in LabVIEW[®].

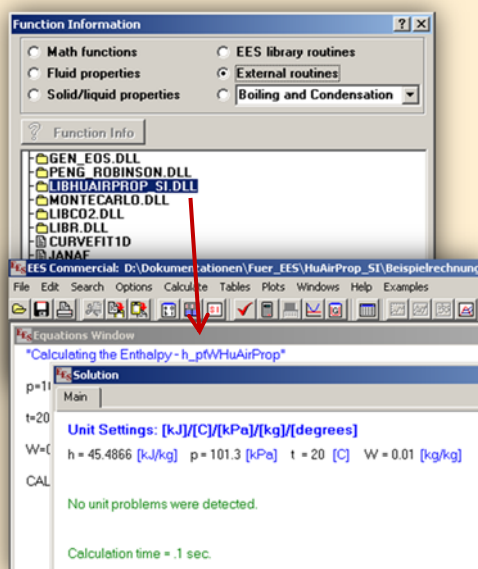


Add-In FluidDYM for DYMOLA[®] (Modelica) and SimulationX[®]

The property functions can be called in DYMOLA[®] and SimulationX[®].



Add-In FluidEES for Engineering Equation Solver®



App International Steam Tables for iPhone, iPad, iPod touch, Android smart phones and tablets



Online Property Calculator at www.thermodynamics-zittau.de

Zittau's Fluid Property Calculator

Fluid:

Function:

Unit System:

Enter given values: [Range of validity](#)

Pressure p: bar

Temperature t: °C

Vapor fraction x: kg/kg

Calculate / Recalculate

Result:

Specific enthalpy h = 3097.38 kJ/kg

For further information on property libraries available for EXCEL®, MATLAB®, Mathcad®, Engineering Equation Solver®, DYMOLA® (Modelica), SimulationX®, and LabView® click [here](#)

An App for calculating steam properties on iPhone, iPad, and iPod touch can be found [here](#)

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E-mail: info@thermodynamics-zittau.de
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Property Software for Pocket Calculators

FluidCasio



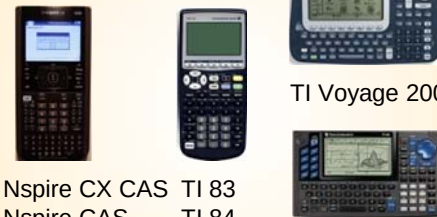
fx 9750 G II CFX 9850 fx-GG20 CFX 9860 G Graph 85 ALGEBRA FX 2.0

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TI Nspire CX CAS TI Nspire CAS TI Voyage 200
TI 83 TI 84 TI 89 TI 92

For more information please contact:

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The following thermodynamic and transport properties^a can be calculated in Excel®, MATLAB®, Mathcad®, Engineering Equation Solver® EES, DYMOLA® (Modelica), SimulationX®, and LabVIEW®:

Thermodynamic Properties

- Vapor pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- Prandtl-number Pr

Backward Functions

- $T, v, s(p, h)$
- $T, v, h(p, s)$
- $p, T, v(h, s)$
- $p, T(v, h)$
- $p, T(v, u)$

Thermodynamic Derivatives

- Partial derivatives can be calculated.

^a Not all of these property functions are available in all property libraries.

6. References

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- [2] Verein Deutscher Ingenieure; VDI- Gesellschaft Verfahrenstechnik und Chemieingenieurwesen (GVC): *VDI Wärmeatlas 10th edition*. Berlin, Heidelberg: Springer-Verlag 2006
- [3] *VDI Heat Atlas*. Berlin, Heidelberg: Springer-Verlag 2010

7. Satisfied Customers

Date: 04/2014

The following companies and institutions use the property libraries

- FluidEXL *Graphics* for Excel®
- FluidLAB for MATLAB®
- FluidMAT for Mathcad®
- FluidEES for Engineering Equation Solver® EES
- FluidDYM for Dymola® (Modelica) and SimulationX®
- FluidVIEW for LabVIEW®:

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EnviCon & Plant Engineering, Nuremberg	11/2003
Visteon, Kerpen	11/2003
VEO Vulkan Energiewirtschaft Oderbruecke, Eisenhuettenstadt	11/2003
Stadtwerke Hannover	11/2003
SaarEnergie, Saarbruecken	11/2003
Fraunhofer-Gesellschaft, Munich	12/2003
Erfurt University of Applied Sciences, Department of Supply Engineering	12/2003
SorTech, Freiburg	12/2003
Mainova, Frankfurt	12/2003
Energieversorgung Halle	12/2003

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Hamilton Medical AG, Rhaezuens, Switzerland	01/2002
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SAAS, Possendorf/Dresden	02/2002
Siemens, Karlsruhe (general license for the WinIS information system)	02/2002
FZR Forschungszentrum, Rossendorf/Dresden	03/2002

CompAir, Simmern	03/2002
GKS Gemeinschaftskraftwerk, Schweinfurt	04/2002
ALSTOM Power Baden, Switzerland (group licenses)	05/2002
InfraServ, Gendorf	05/2002
SoftSolutions, Muehlhausen (company license)	05/2002
DREWAG, Dresden (company license)	05/2002
SOFBID, Zwingenberg (general EBSILON program license)	06/2002
Kleemann Engineering, Dresden	06/2002
Caliqua, Basel, Switzerland (company license)	07/2002
PCK Raffinerie, Schwedt (group license)	07/2002
Fischer-Uhrig Engineering, Berlin	08/2002
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	08/2002
Stadtwerke Duisburg	08/2002
Stadtwerke Hannover	09/2002
Siemens Power Generation, Goerlitz	10/2002
Energieversorgung Halle (company license)	10/2002
Bayer, Leverkusen	11/2002
Dillinger Huette, Dillingen	11/2002
G.U.N.T. Geraetebau, Barsbuettel (general license and training test benches)	12/2002
VEAG, Berlin (group license)	12/2002

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ALSTOM Power, Baden, Switzerland	01/2001, 06/2001 12/2001
KW2 B. V., Amersfoot, Netherlands	01/2001, 11/2001
Eco Design, Saitamaken, Japan	01/2001
M&M Turbine Technology, Bielefeld	01/2001, 09/2001
MVV Energie, Mannheim	02/2001
Technical University of Dresden, Department of Power Machinery and Plants	02/2001
PREUSSAG NOELL, Wuerzburg	03/2001
Fichtner Consulting & IT Stuttgart (company licenses and distribution)	04/2001
Muenstermann GmbH, Telgte-Westbevern	05/2001
SaarEnergie, Saarbruecken	05/2001

Siemens, Karlsruhe (general license for the WinIS information system)	08/2001
Neusiedler AG, Ulmerfeld, Austria	09/2001
h s energieanlagen, Freising	09/2001
Electrowatt-EKONO, Zurich, Switzerland	09/2001
IPM Zittau/Goerlitz University of Applied Sciences (general license)	10/2001
eta Energieberatung, Pfaffenhofen	11/2001
ALSTOM Power Baden, Switzerland	12/2001
VEAG, Berlin (group license)	12/2001

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SOFBID, Zwingenberg (general EBSILON program license)	01/2000
AG KKK - PGW Turbo, Leipzig	01/2000
PREUSSAG NOELL, Wuerzburg	01/2000
M&M Turbine Technology, Bielefeld	01/2000
IBR Engineering Reis, Nittendorf-Undorf	02/2000
GK, Hannover	03/2000
KRUPP-UHDE, Dortmund (company license)	03/2000
UMAG W. UDE, Husum	03/2000
VEAG, Berlin (group license)	03/2000
Thinius Engineering, Erkrath	04/2000
SaarEnergie, Saarbruecken	05/2000, 08/2000
DVO Data Processing Service, Oberhausen	05/2000
RWTH Aachen University	06/2000
VAUP Process Automation, Landau	08/2000
Knuerr-Lommatec, Lommatzsch	09/2000
AVACON, Helmstedt	10/2000
Compania Electrica, Bogota, Colombia	10/2000
G.U.N.T. Geraetebau, Barsbuettel (general license for training test benches)	11/2000
Steinhaus Informationssysteme, Datteln (general license for process data software)	12/2000

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Bayernwerk, Munich	01/1999
DREWAG, Dresden (company license)	02/1999
KEMA IEV, Dresden	03/1999

Regensburg University of Applied Sciences	04/1999
Fichtner Consulting & IT, Stuttgart (company licenses and distribution)	07/1999
Technical University of Cottbus, Chair in Power Plant Engineering	07/1999
Technical University of Graz, Department of Thermal Engineering, Austria	11/1999
Ostendorf Engineering, Gummersbach	12/1999

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Technical University of Cottbus, Chair in Power Plant Engineering	05/1998
Fichtner Consulting & IT (CADIS information systems) Stuttgart (general KPRO program license)	05/1998
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B+H Software Engineering Stuttgart	08/1998
Alfa Engineering, Switzerland	09/1998
VEAG Berlin (group license)	09/1998
NUTEC Engineering, Bisikon, Switzerland	10/1998
SCA Hygiene Products, Munich	10/1998
RWE Energie, Neurath	10/1998
Wilhelmshaven University of Applied Sciences	10/1998
BASF, Ludwigshafen (group license)	11/1998
Energieversorgung, Offenbach	11/1998

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Gerb, Dresden	06/1997
Siemens Power Generation, Goerlitz	07/1997