

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

**FluidEXL Graphics  
with LibHeatEx  
for Excel®**

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# **Software for the Calculation of the Properties of Heat Exchangers**

## **Including DLL and Add-In for Excel®**

### **FluidEXL Graphics**

### **LibHeatEx**

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# **0 Package Contents**

## **0.1 Zip files for 64-bit Office®**

The following zip file has been delivered for your computer running a 64-bit Office® version:

CD\_FluidEXL\_Graphics\_Eng\_LibHeatEx\_x64.zip

including the following folders and files:

\FLUFT\  
\Formulation97\  
FluidEXL\_Graphics\_LibHeatEx\_Docu\_Eng.pdf  
FluidEXL\_Graphics\_Eng.xla  
LC.dll  
LibHeatEx.dll  
LibHeatEx.chm.

## **0.2 Zip files for 32-bit Office®**

The following zip file has been delivered for your computer running a 32-bit Office® version:

CD\_FluidEXL\_Graphics\_Eng\_LibHeatEx.zip

including the following folders and files:

\FLUFT\  
\Formulation97\  
FluidEXL\_Graphics\_LibHeatEx\_Docu\_Eng.pdf  
FluidEXL\_Graphics\_Eng.xla  
LC.dll  
LibHeatEx.dll  
LibHeatEx.chm.

# 1. Property Functions

## 1.1 Functions

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

**Units:** All quantities are dimensionless.

**Equations:**

Dimensionless temperature changes

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

Determination:

A – heating surface

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

$c_p$  – heat capacity

$k$  - heat transfer coefficient

Number of transfer units

$$\frac{k \cdot A}{C_A} = \frac{\Delta \vartheta_A}{\Delta \vartheta_{AB}^m} = \frac{k \cdot A}{\dot{C}_B} \cdot \frac{\dot{C}_B}{\dot{C}_A}$$

Indexing:

A – flow A

B – flow B

$$\frac{k \cdot A}{C_B} = \frac{\Delta \vartheta_B}{\Delta \vartheta_{AB}^m} = \frac{k \cdot A}{\dot{C}_A} \cdot \frac{\dot{C}_A}{\dot{C}_B}$$

H – heating medium

Ratios of the heat capacity rate

$$\frac{\dot{C}_A}{\dot{C}_B} = \frac{\Delta \vartheta_B}{\Delta \vartheta_A}$$

$$\frac{\dot{C}_B}{\dot{C}_A} = \frac{\Delta \vartheta_A}{\Delta \vartheta_B}$$

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

$\Delta t_A$  - temperature changes flow A

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

$\Delta t_B$  - temperature changes flow B

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

$c_{pA}^m$  - 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  $\Phi$ , 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  $\Phi = \Phi(\frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B})$ . In most cases the

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

and  $\frac{\dot{C}_A}{\dot{C}_B} = f(\Phi, \frac{k \cdot A}{\dot{C}_A})$ , 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

$$\Phi_A = f(I_{TYPE}, \frac{k \cdot A}{\dot{C}_A}, \frac{\dot{C}_A}{\dot{C}_B}, N_{SPEC}),$$

$$\frac{k \cdot A}{\dot{C}_A} = f(I_{TYPE}, \Phi_A, \frac{\dot{C}_A}{\dot{C}_B}, N_{SPEC}), \text{ and}$$

$$\frac{\dot{C}_A}{\dot{C}_B} = f(I_{TYPE}, \Phi_A, \frac{k \cdot A}{\dot{C}_A}, N_{SPEC}).$$

The dependencies for flow B are

$$\Phi_B = f(I_{TYPE}, \frac{k \cdot A}{\dot{C}_B}, \frac{\dot{C}_B}{\dot{C}_A}, N_{SPEC}),$$

$$\frac{k \cdot A}{\dot{C}_B} = f(I_{TYPE}, \Phi_B, \frac{\dot{C}_B}{\dot{C}_A}, N_{SPEC}), \text{ and}$$

$$\frac{\dot{C}_B}{\dot{C}_A} = f(I_{TYPE}, \Phi_B, \frac{k \cdot A}{\dot{C}_B}, N_{SPEC}).$$

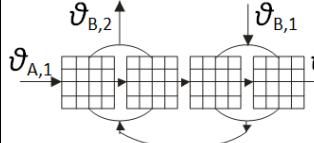
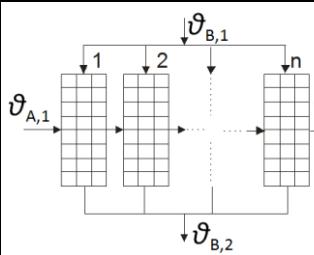
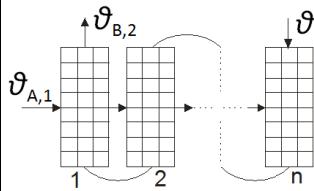
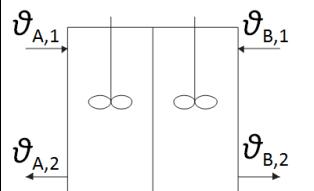
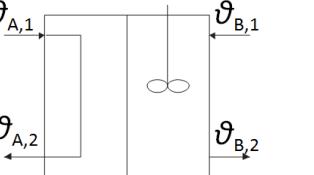
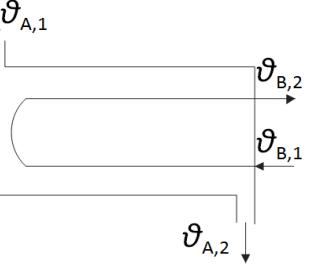
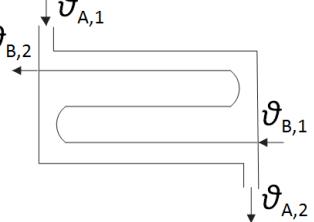
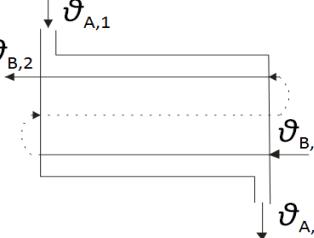
The range of validity for the different parameters are shown in the following Table 1

**Table 1: Range of validity**

Quantities	Range of validity
Dimensionless temperature changes:	$0 \leq \Phi_i \leq 1$
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**

HYPE	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
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

$h_{\text{TYPE}}$	Type	Flow arrangement	$N_{\text{SPEC}}$
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
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 Water and Steam from the LibHeatEx property program library.

### 2.1 Installing FluidEXL Graphics

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

Before you begin, it is best to uninstall any older version of FluidEXL *Graphics*.

The installation routine for 32-bit and 64-bit versions of Excel is similar. The following instructions are valid for both versions.

After you have downloaded and extracted the zip-file:

CD\_FluidEXL\_Graphics\_LibHeatEx\_x64\_Eng.zip (for 64 bit version)

or

CD\_FluidEXL\_Graphics\_LibHeatEx\_Eng.zip" (for 32 bit version).

you will see the folder

\CD\_FluidEXL\_Graphics\_LibHeatEx\_x64\_Eng\ (for 64 bit version)

or

\CD\_FluidEXL\_Graphics\_LibHeatEx\_Eng\ (for 32 bit version)

in your Windows Explorer, Total Commander etc.

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

Within this folder you will see the following folders and files:

\FLUFT\

\Formulation97\

FluidEXL\_Graphics\_Eng.xla

FluidEXL\_Graphics\_LibHeatEx\_Docu\_Eng

LC.dll

LibHeatEx.dll

LibHeatEx.chm

Reg\_.reg

Now, please copy the following folders and files

\FLUFT\

\Formulation97\

FluidEXL\_Graphics\_Eng.xla

LibHeatEx.dll

LibHeatEx.chm

LC.dll

into the folder

C:\Users\[your name]\AppData\Roaming\Microsoft\AddIns\,

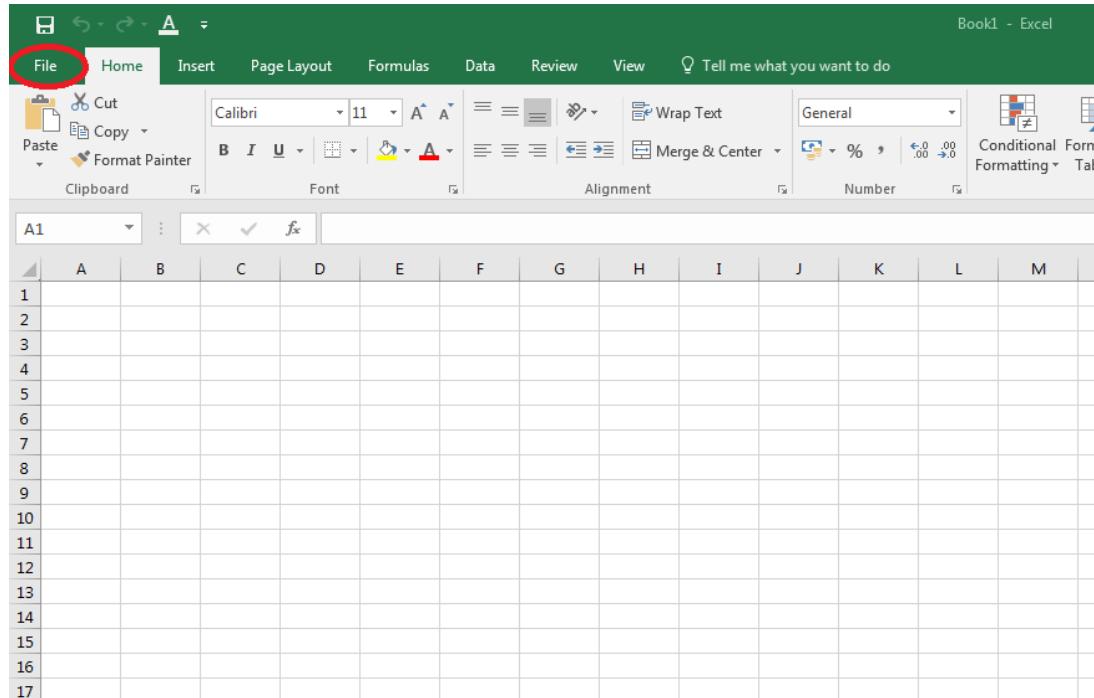
where [your name] is your name in the Windows system.

If this folder is not found, follow the next section anyway.

## 2.2 Registering FluidEXL Graphics as Add-In in Excel®

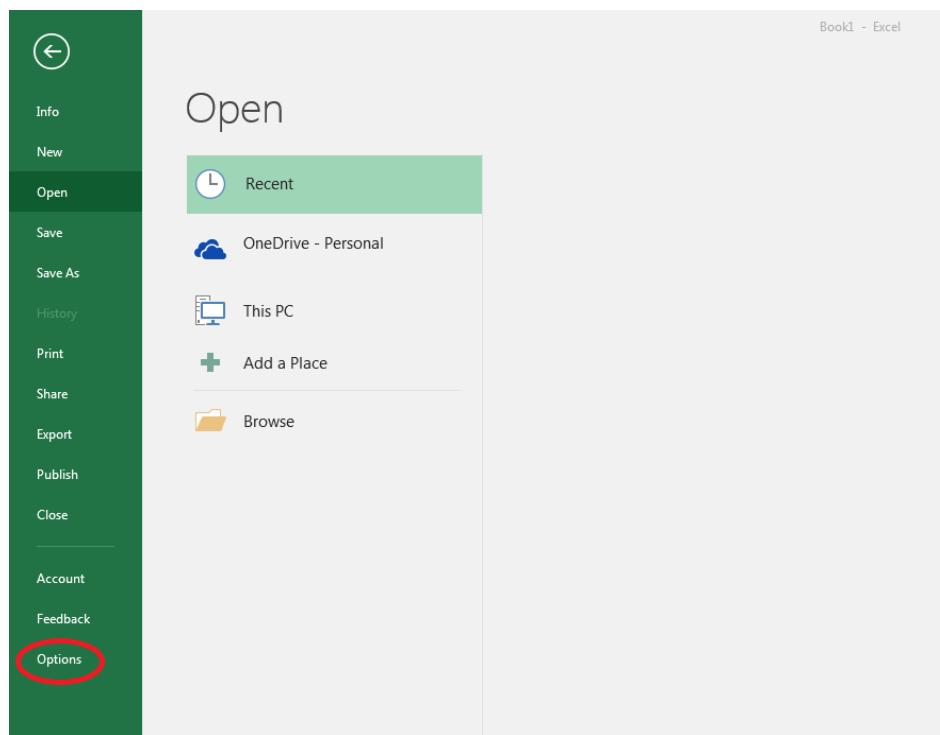
After installation in Windows®, FluidEXL *Graphics* must be registered in Excel® as an Add-In. To do this, start Excel® and carry out the following steps:

- Click the "File" button in the upper left hand corner of Excel® (see Fig. 2.1)



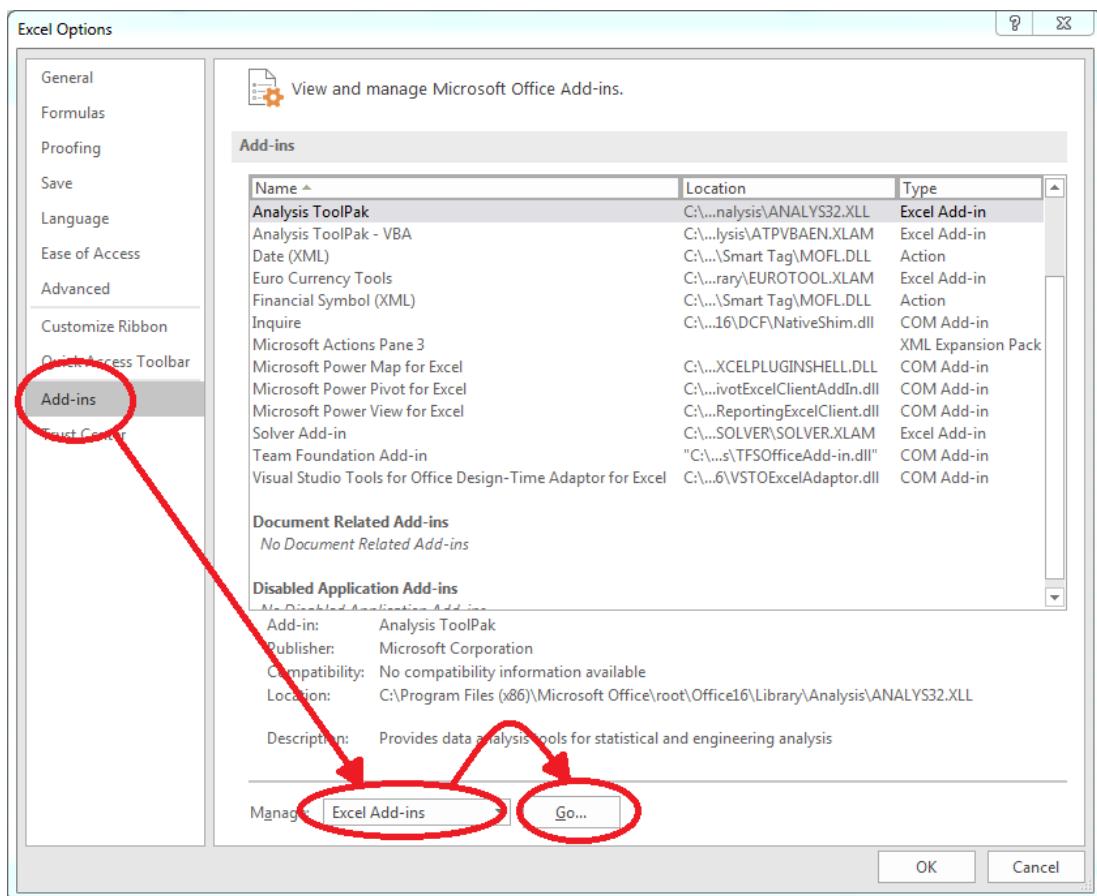
**Figure 2.1:** Registering FluidEXL *Graphics* as Add-In in Excel® 2016

- Click on the "Options" button in the menu which appears (see Fig. 2.2)



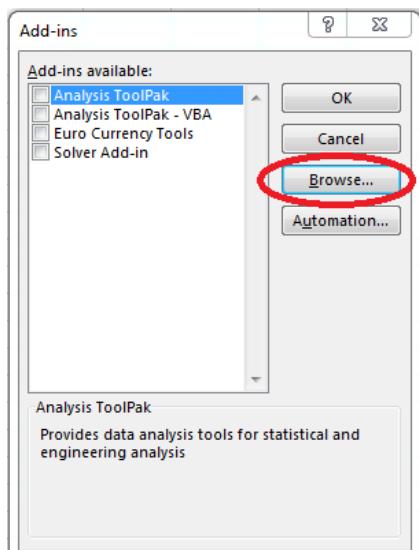
**Figure 2.2:** Registering FluidEXL *Graphics* as Add-In in Excel® 2016

- Click on "Add-Ins" in the next menu (Fig. 2.3)



**Figure 2.3:** Dialog window "Excel Options"

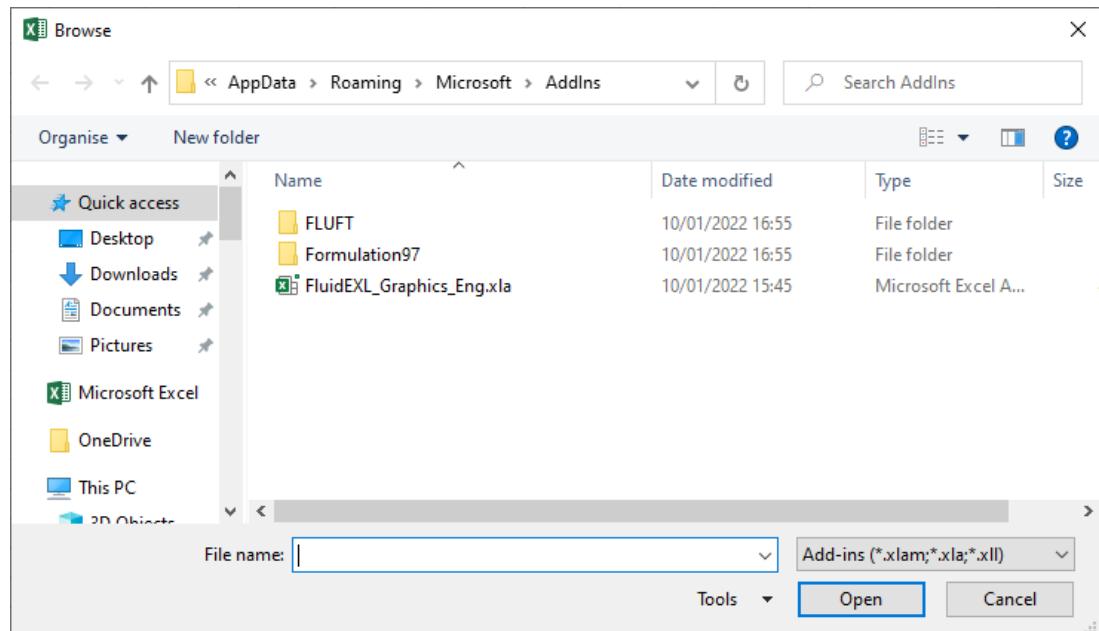
- Select "Excel Add-ins" next to "Manage:" in the lower area of the menu
- Then click the "Go..." button
- Click "Browse" in the following window (Fig. 2.4)



**Figure 2.4:** Dialog window "Add-ins"

- Excel opens the AddIns folder. This is usually [C:\Users\\[your name\]\AppData\Roaming\Microsoft>AddIns](C:\Users\[your name]\AppData\Roaming\Microsoft>AddIns).
- If the FluidEXL files have already been copied to this directory in section 2.1, please skip the following indented section. If not, follow the indented instructions to successful paste the needed files for the FluidEXL Add-In:

In the upper part of the "Browse" window the correct Add-In path is displayed (see Figure 2.5). Please note that not the entire path is displayed.



**Figure 2.5:** "Browse"-Window

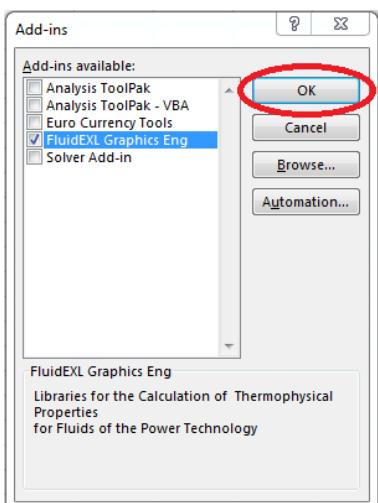
Please copy this path and paste it into your file manager.

Now, please copy the following directories and files:

\FLUFT\  
 \Formulation97\  
 LC.dll  
 FluidEXL\_Graphics\_Eng.xla  
 LibHeatEx.dll  
 LibHeatEx.chm

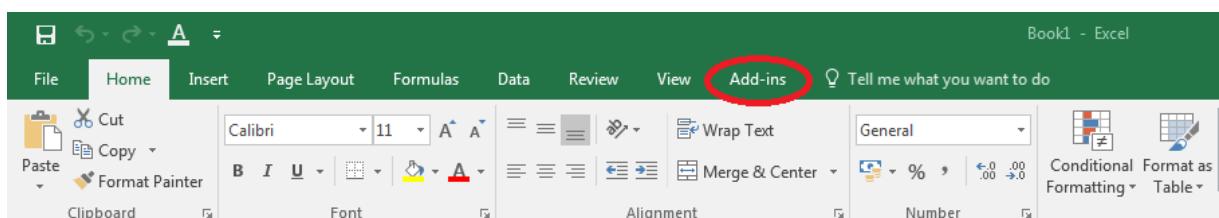
from the delivered CD-folder into this folder.

- Click "FluidEXL\_Graphics\_Eng.xla" in this folder (see Fig. 2.5) and click "OK."
- Now, "FluidEXL Graphics Eng" will be shown in the list of Add-ins (see Fig. 2.6). (If a checkmark is 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 checkmark is removed from the box by clicking on it.)
- In order to register the Add-In click the "OK" button in the "Add-ins" window (see Fig. 2.6).



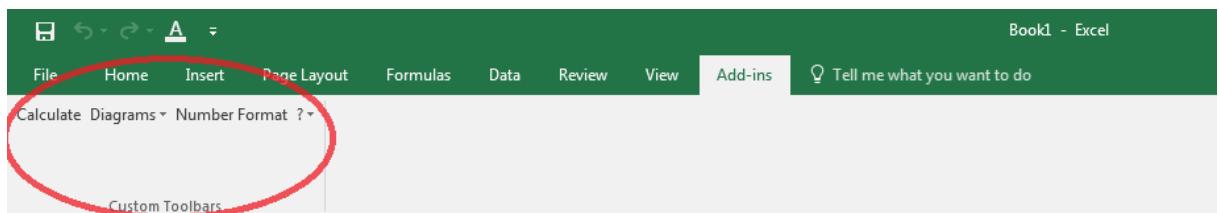
**Figure 2.6:** Dialog window "Add-Ins"

In order to use FluidEXL *Graphics* in the following example, click on the menu item "Add-Ins" shown in Fig. 2.7.



**Figure 2.7:** 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 Fig. 2.8.



**Figure 2.8:** FluidEXL *Graphics* menu bar

The Installation of FluidEXL *Graphics* in Excel® is now complete.

An example calculation of "LibHeatEx" DLL library property functions can be found in chapter 2.4.

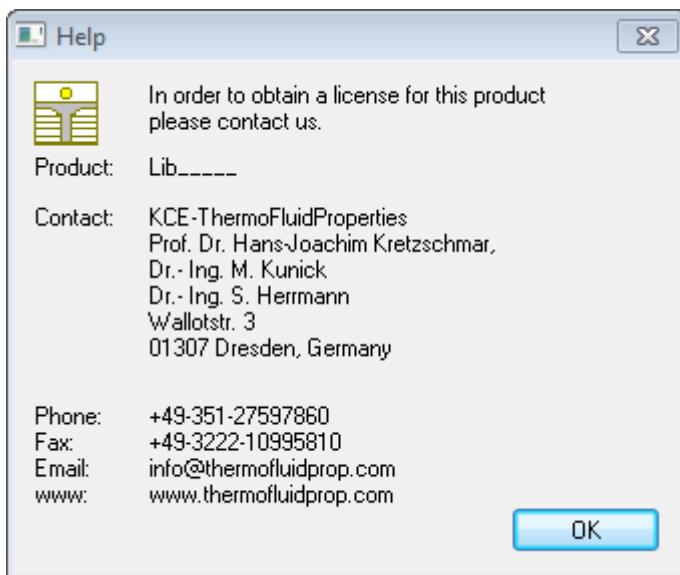
### 2.3 Licensing the LibHeatEx Property LibHeatExrary

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 2.12:** "License Information" window

Here you will have to type in the license key. 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 2.13:** "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 "-11111111" 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.chm

in the installation folder of FluidEXL\_Graphics (the standard being)

C:\Program Files\FluidEXL\_Graphics\_Eng

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

#### **Note:**

The product name "LibHeatEx\_ \_ \_ \_ \_ in Figure 2.12 and 2.13 stands for the LibHeatEx library you are installing. In this case it is the LibHeatEx library.

## 2.4 Example calculation

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

The following quantities are given:

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

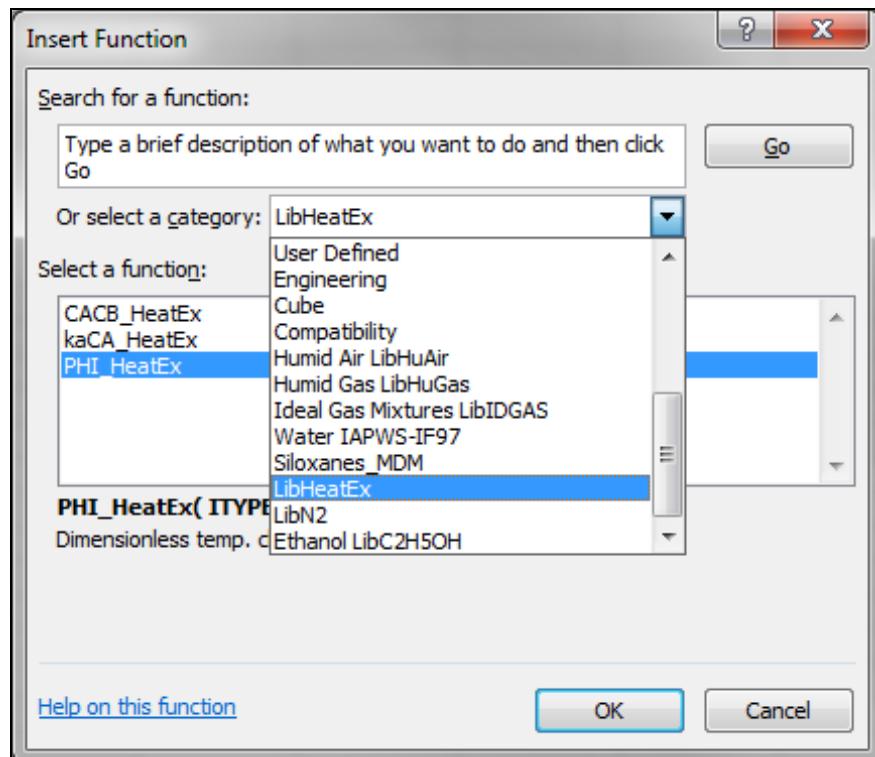
$$\frac{\dot{C}_A}{\dot{C}_B} = 0.5$$

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

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

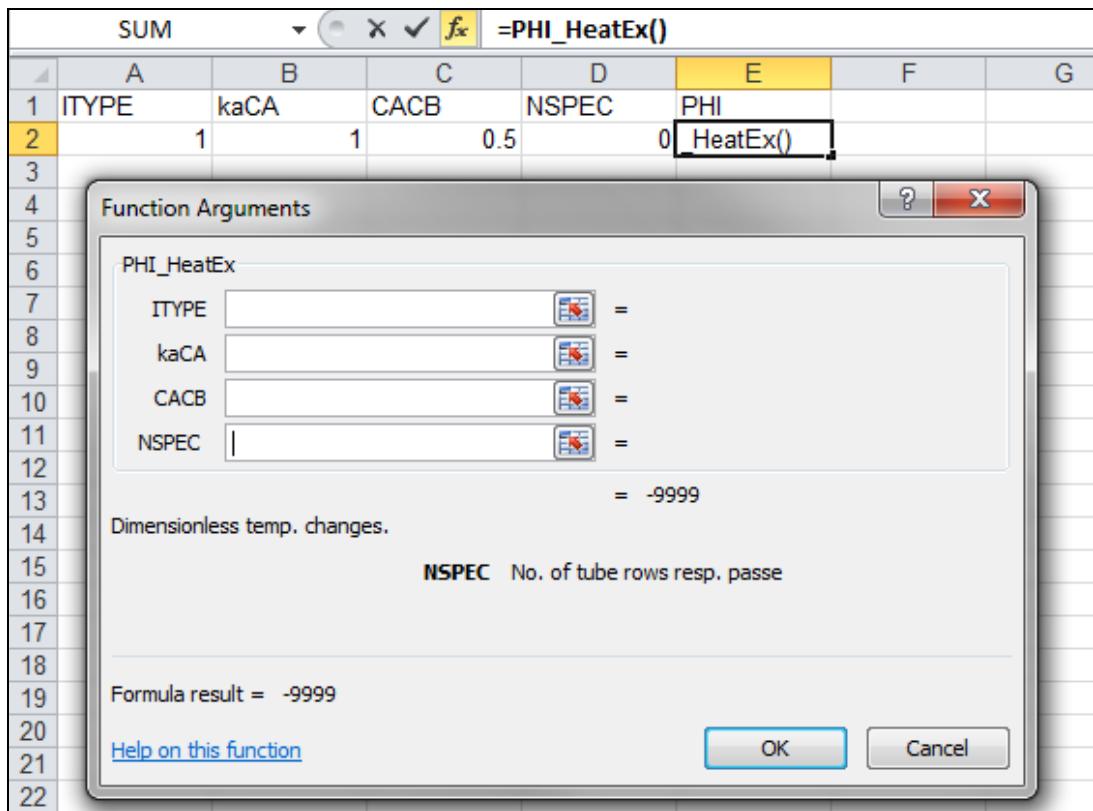
Number of tube rows or passes:  $N_{\text{SPEC}} = 0$

- Start Excel®
- Enter the value for  $I_{\text{TYPE}}$  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  $N_{\text{SPEC}}$  in a cell  
⇒ e. g.: Enter the value 0 into cell D2
- Click the cell in which the value of the dimensionless temperature changes  $\phi$  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 2.14).



**Figure 2.14:** Choice of library and function name

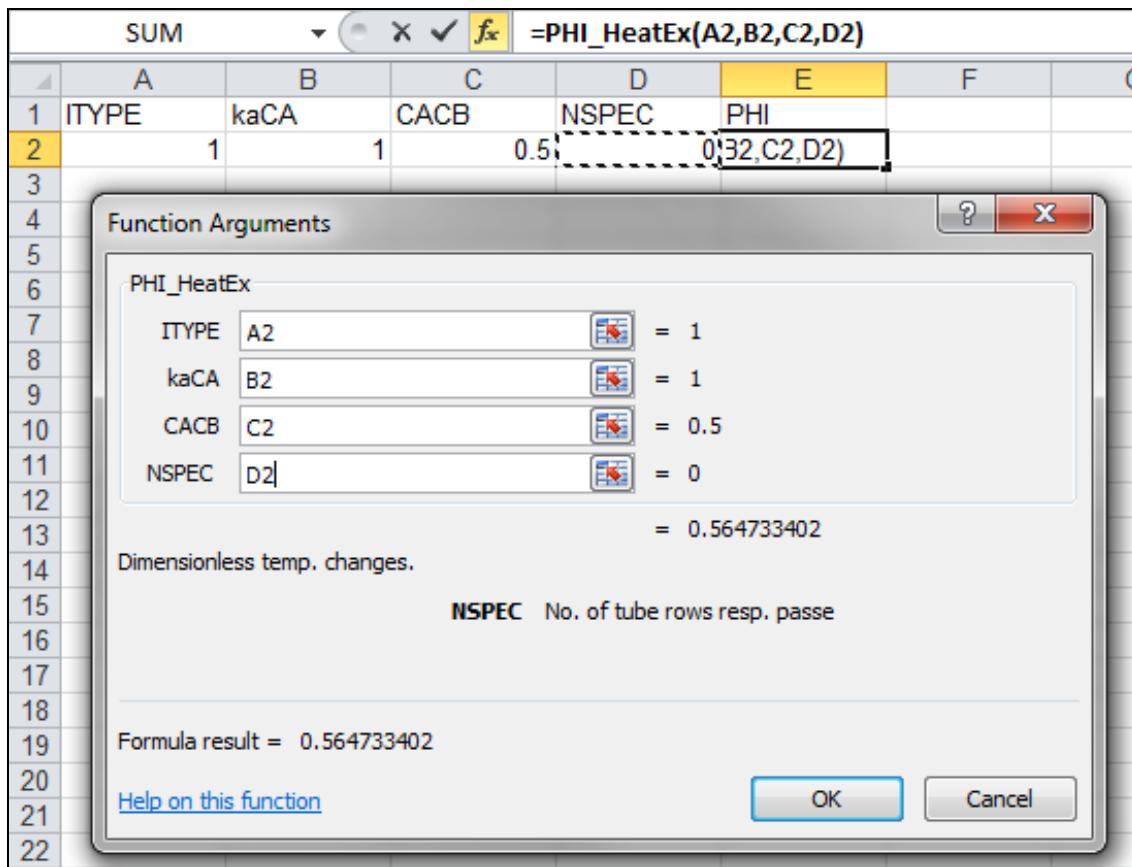
- Search and click the "LibHeatEx" library under "Or select a category:" in the upper part of the window.
- Search and click the PHI\_HeatEx function under "Select a function:" right below. Here it is possible to get more information on the range of validity, measuring units, error responses, etc. by clicking the "Help on this function" button.
- Click "OK".  
The window shown in Figure 2.15 will now appear.



**Figure 2.15:** 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 2.16:** Input menu showing the result

- Click the "OK" button.

The result for  $\phi$  appears in the cell selected above.

⇒ The result in our sample calculation here is:

dimensionless temperature changes  $\phi = 0.564733402$ .

The calculation of  $\Phi$  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<sup>Graphics</sup>, 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

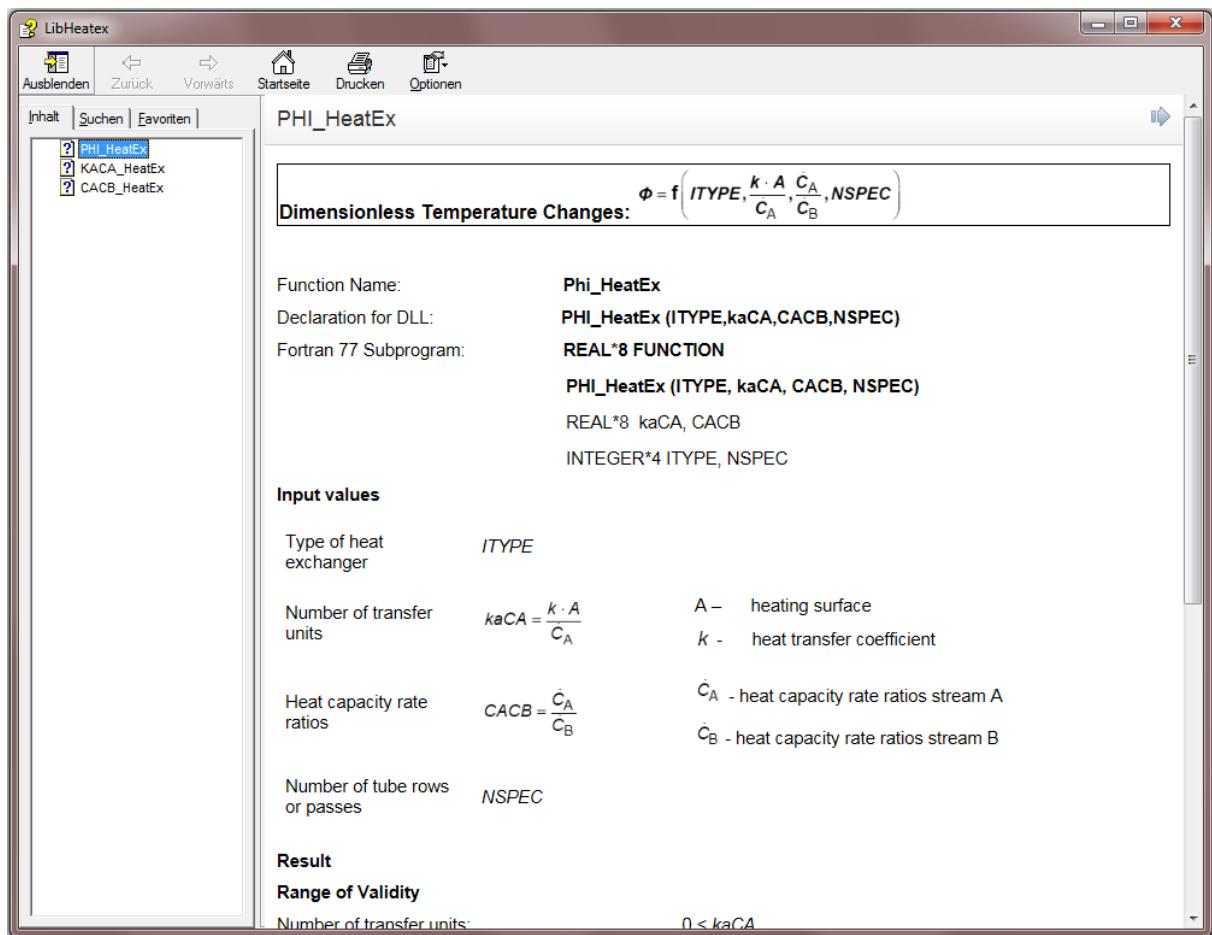
This formatting can also be applied to cells which have already been calculated.

## 2.5 The FluidEXL Graphics Help System

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

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

- Click "Calculate" in the FluidEXL *Graphics* menu bar.
- Click on the "LibHeatEx" 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.



**Figure 2.17:** Help Window

If the LibHeatEx.chm function help cannot be found, you will be redirected to a Microsoft® help website by your standard browser. In this case, the LibHeatEx.chm file has to be copied into the folder of FluidEXL *Graphics*, in the standard case

C:\Program Files\FluidEXL\_Graphics\_Eng  
 to use the help system.

## 2.6 Removing FluidEXLGraphics

### 2.6.1 Removing LibHeatEx Library

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

LibHeatEx.dll

LibHeatEx.chm

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

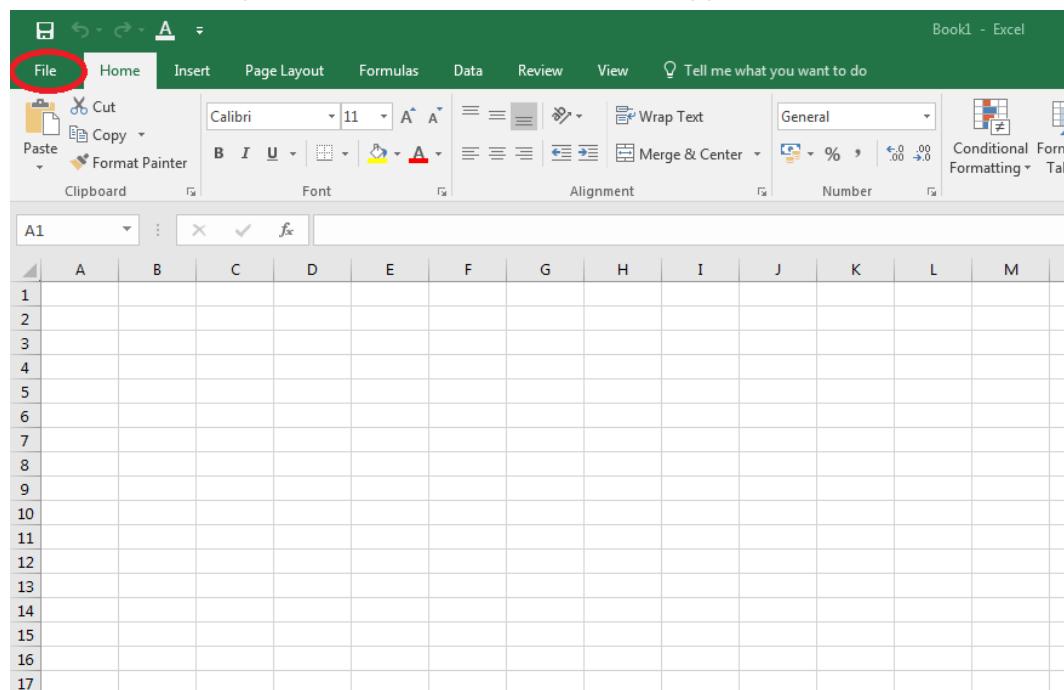
C:\Program Files\FluidEXL\_Graphics\_Eng

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

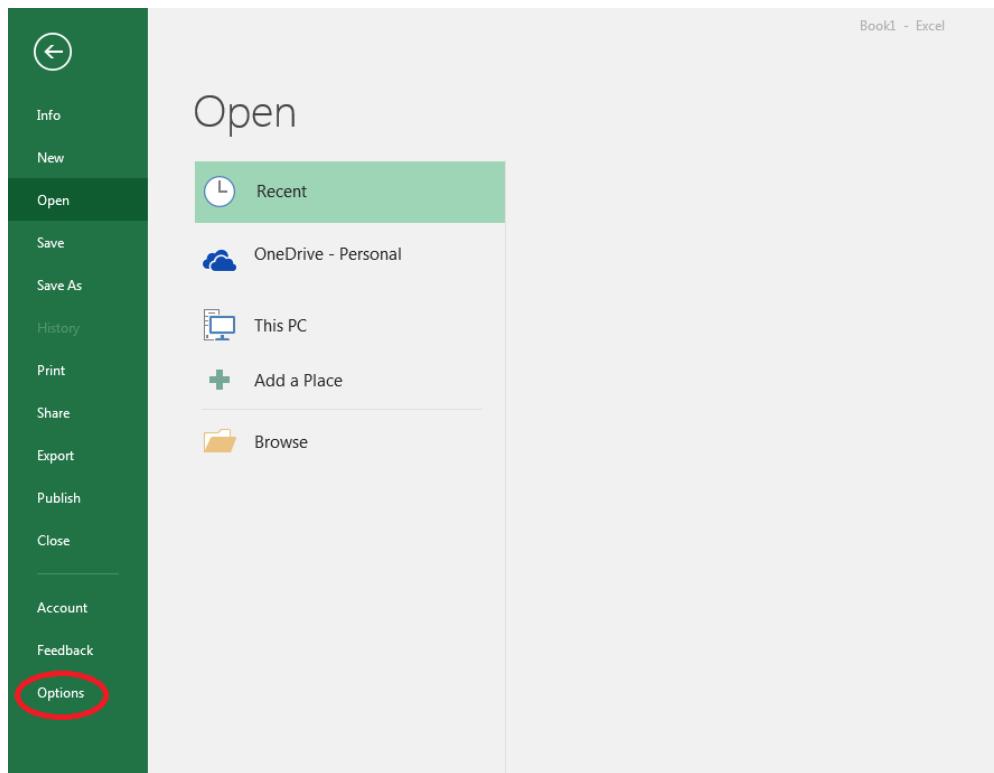
### 2.6.2 Unregistering and uninstalling FluidEXL *Graphics* as Add-In in versions of Excel® from 2007 onwards (for earlier versions see 2.6.3)

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

- Click the “File” button in the upper left corner of Excel®
- Click on the "Options" button in the menu which appears

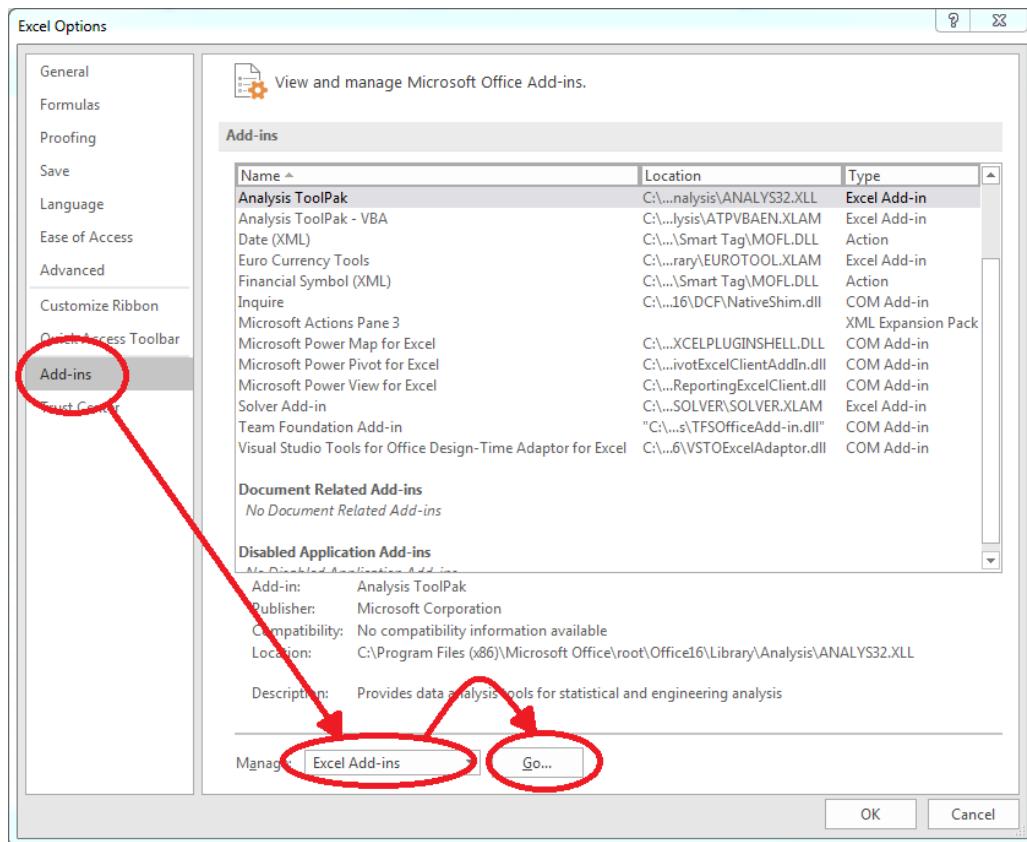


**Figure 2.18:** Unregistering FluidEXL *Graphics* as Add-In in Excel® 2016



**Figure 2.19** Unregistering FluidEXL Graphics as Add-In in Excel® 2016

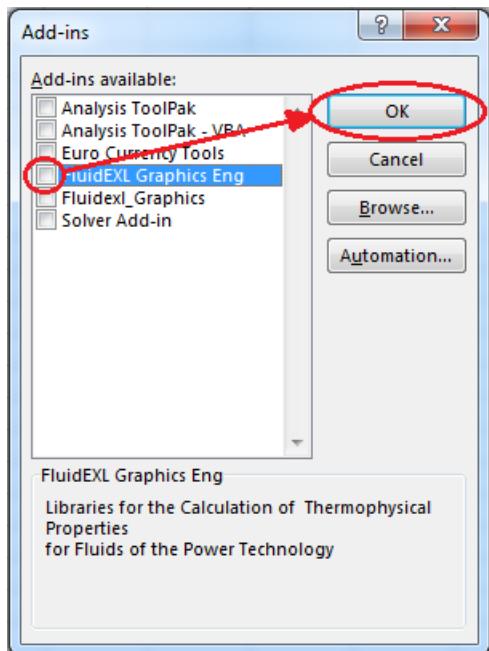
- Click on "Add-Ins" in the next menu (Figure 2.20)



**Figure 2.20:** 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"
- in the window which now appears. Click the "OK" button to confirm your entry.



**Figure 2.20:** 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"

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.

### 2.6.3 Unregistering and uninstalling 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.xls

has to be cancelled in Excel®.

In order to do this, 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"

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"

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.chm

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

C:\Program Files\FluidEXL\_Graphics\_Eng

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

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/Remove Programs" window that appears select

"FluidEXL Graphics Eng"

by clicking on it and click the "Add/Remove..." button. In the following dialog box, click "Automatic" and then "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.

### 3. Program Documentation

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

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 **ITYPE**

Number of transfer units  $kaCA = \frac{k \cdot A}{C_A}$  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 **NSPEC**

#### Result

**PHI\_HeatEx** – Dimensionless temperature changes

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

	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]

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

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	$\Phi = Phi = \frac{t_{A1} - t_{A2}}{t_{A1} - t_{B1}} = \frac{\Delta \vartheta_A}{\Delta \vartheta_{AB}^{\max}}$	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]

<b>Heat Capacity Rate Ratios:</b>	$\frac{\dot{C}_A}{\dot{C}_B} = f(I TYPE, \Phi, \frac{k \cdot A}{\dot{C}_A}, NSPEC)$
-----------------------------------	---

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 *ITYPE*

Dimensionless temperature changes  $\Phi = Phi = \frac{t_{A1} - t_{A2}}{t_{A1} - t_{B1}} = \frac{\Delta \vartheta_A}{\Delta \vartheta_{AB}^{\max}}$

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 *NSPEC*

### 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]

## 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, -S03rev, -S04, and -S05
- IAPWS Revised Advisory Note No. 3 on Thermo-dynamic Derivatives (2008)

#### Library LibIF97\_META

- Industrial Formulation IAPWS-IF97 (Revision 2007) for metastable steam

### Humid Combustion Gas Mixtures

#### Library LibHuGas

Model: Ideal mixture of the real fluids:  
 $\text{CO}_2$  - Span, Wagner     $\text{H}_2\text{O}$  - IAPWS-95  
 $\text{O}_2$  - Schmidt, Wagner     $\text{N}_2$  - Span et al.  
Ar - Tegeler et al.  
and of the ideal gases:  
 $\text{SO}_2$ ,  $\text{CO}$ ,  $\text{Ne}$   
(Scientific Formulation of Bücker et al.)

Consideration of:

- Dissociation from VDI 4670
- 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 VDI 4670
- Poynting effect from ASHRAE RP-1485

### Extremely Fast Property Calculations

Spline-Based Table Look-up Method (SBTL)

#### Library LibSBTL\_IF97

#### Library LibSBTL\_95

#### Library LibSBTL\_HuAir

For steam, water, humid air, carbon dioxide and other fluids and mixtures according IAPWS Guideline 2015 for Computational Fluid Dynamics (CFD), real-time and non-stationary simulations

### 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	$\text{H}_2\text{O}$	$\text{F}_2$	Propane
$\text{N}_2$	$\text{SO}_2$	$\text{NH}_3$	Iso-Butane
$\text{O}_2$	$\text{H}_2$	Methane	n-Butane
CO	$\text{H}_2\text{S}$	Ethane	Benzene
$\text{CO}_2$	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](http://www.ashrae.org/bookstore)

### 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 Bücker and Wagner (2006)

#### n-Butane

#### Library LibButane\_n

Formulation of Bücker 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 the 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

$\text{C}_2\text{H}_6\text{O}_2$	Ethylene glycol
$\text{C}_3\text{H}_8\text{O}_2$	Propylene glycol
$\text{C}_2\text{H}_5\text{OH}$	Ethanol
$\text{CH}_3\text{OH}$	Methanol
$\text{C}_3\text{H}_8\text{O}_3$	Glycerol
$\text{K}_2\text{CO}_3$	Potassium carbonate
$\text{CaCl}_2$	Calcium chloride
$\text{MgCl}_2$	Magnesium chloride
$\text{NaCl}$	Sodium chloride
$\text{C}_2\text{H}_3\text{KO}_2$	Potassium acetate
$\text{CHKO}_2$	Potassium formate
$\text{LiCl}$	Lithium chloride
$\text{NH}_3$	Ammonia

Formulation of the International Institute of Refrigeration (IIR 2010)

## Ethanol

### Library LibC2H5OH

Formulation of Schroeder et al. (2014)

## 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  $C_{14}H_{42}O_5Si_6$  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 and Oxygen

### Libraries

#### LibN2 and LibO2

Formulations of Span et al. (2000) and Schmidt and Wagner (1985)

## 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  $H_2S$  Library LibH2S

Nitrous oxide  $N_2O$  Library LibN2O

Sulfur dioxide  $SO_2$  Library LibSO2

Acetone  $C_3H_6O$  Library LibC3H6O

Formulation of Lemmon and Span (2006)



## For more information please contact:

KCE-ThermoFluidProperties UG & Co. KG

Prof. Dr. Hans-Joachim Kretzschmar

Wallotstr. 3

01307 Dresden, Germany

Internet: [www.thermofluidprop.com](http://www.thermofluidprop.com)

Email: [info@thermofluidprop.com](mailto:info@thermofluidprop.com)

Phone: +49-351-27597860

Mobile: +49-172-7914607

Fax: +49-3222-1095810

## The following thermodynamic and transport properties can be calculated<sup>a</sup>:

### Thermodynamic Properties

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

### Transport Properties

- Dynamic viscosity  $\eta$
- Kinematic viscosity  $\nu$
- Thermal conductivity  $\lambda$
- Prandtl number  $Pr$
- Thermal diffusivity  $a$

### Backward Functions

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

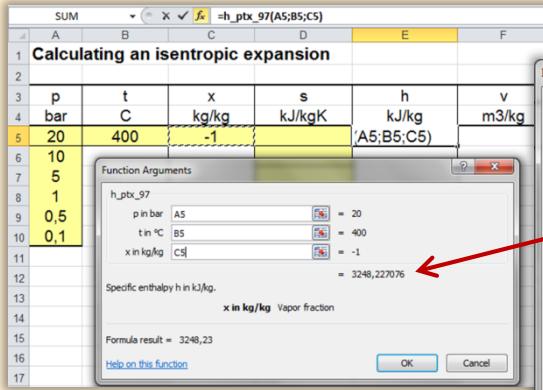
### Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

<sup>a</sup> Not all of these property functions are available in all property libraries.

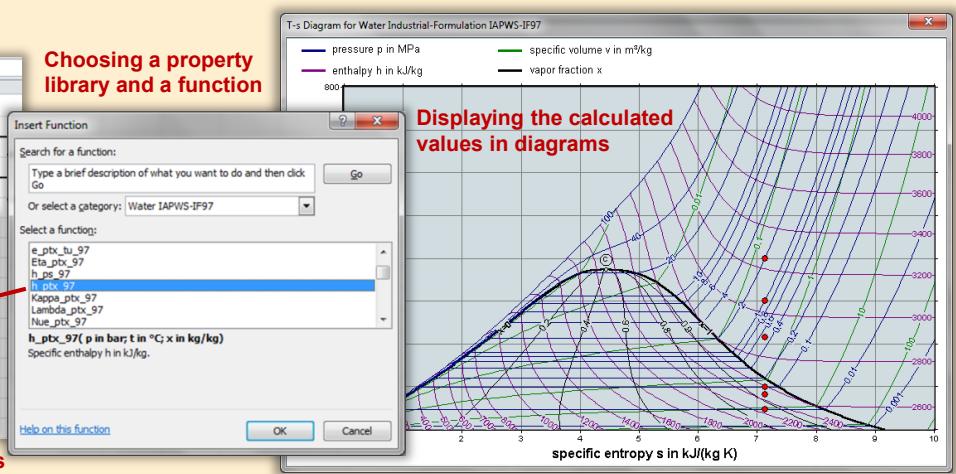
## Property Software for Calculating Heat Cycles, Boilers, Turbines and Refrigerators

### Add-In FluidEXL Graphics for Excel®



Menu for the input of given property values

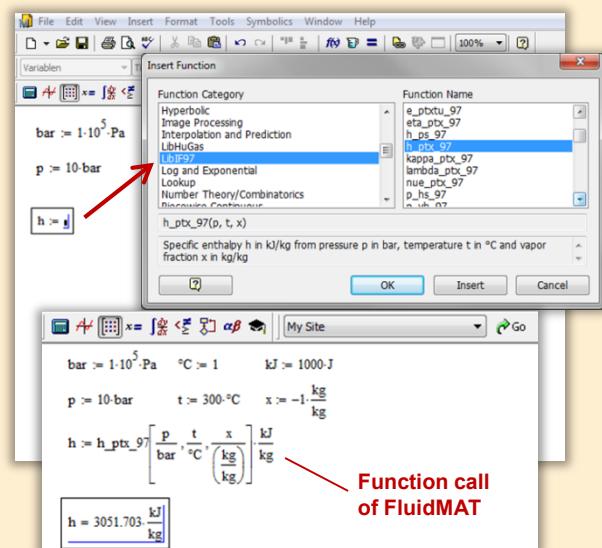
Choosing a property library and a function



### Add-On FluidMAT for Mathcad®

### Add-On FluidPRIME for Mathcad Prime®

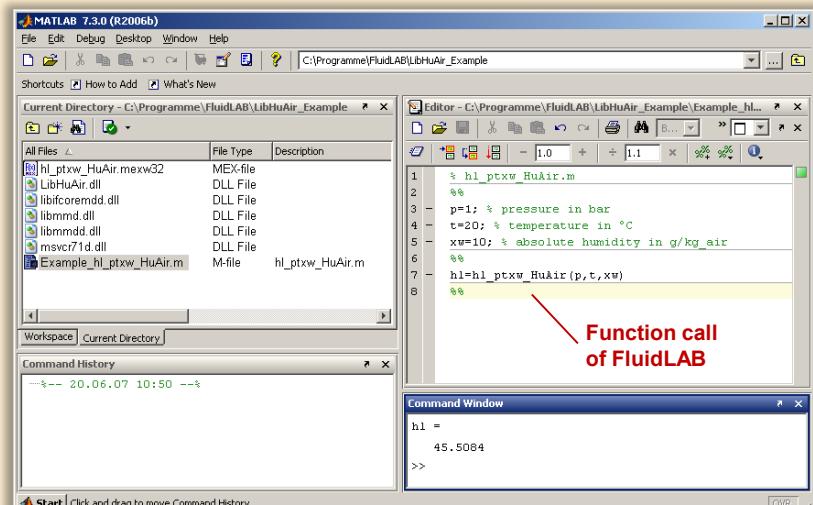
The property libraries can be used in Mathcad® and Mathcad Prime®.



Function call of FluidMAT

### Add-On FluidLAB for MATLAB® and SIMULINK®

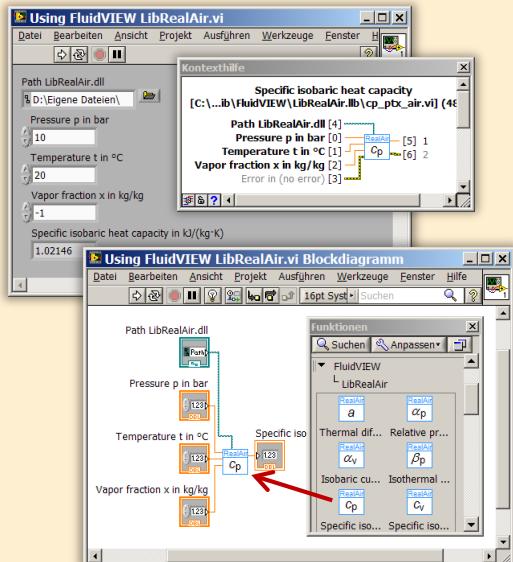
Using the Add-In FluidLAB the property functions can be called in MATLAB® and SIMULINK®.



Function call of FluidLAB

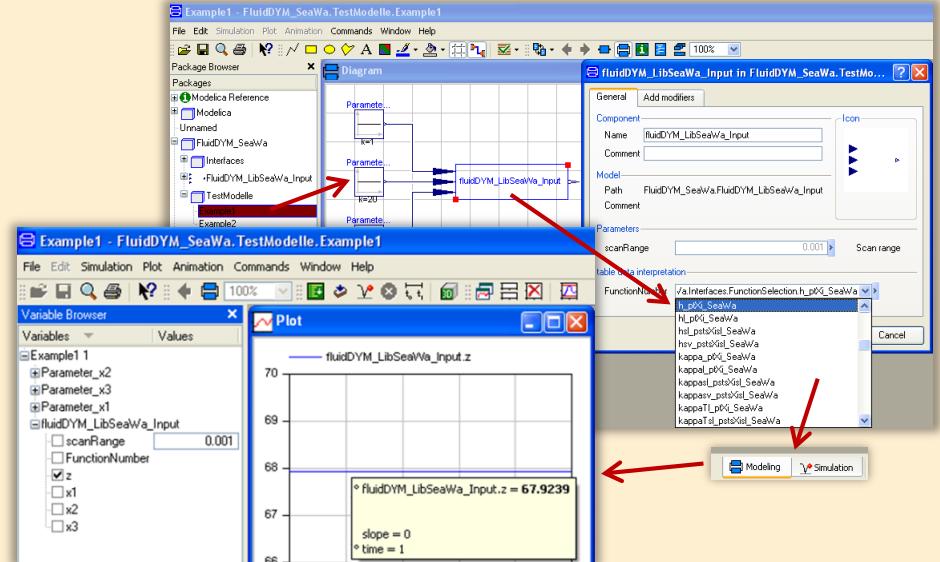
### Add-On FluidVIEW for LabVIEW™

The property functions can be calculated in LabVIEW™.

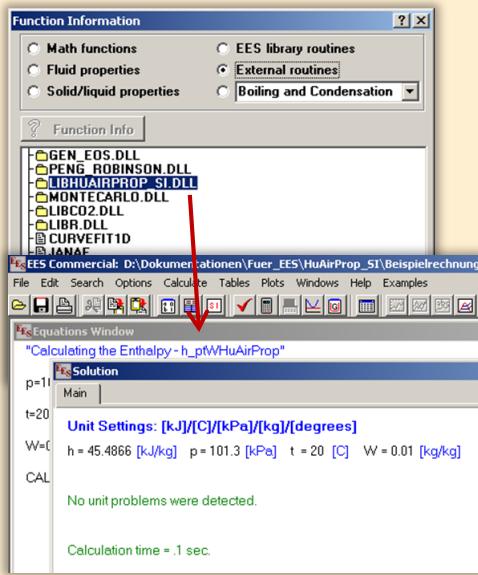


### Add-On FluidDYM for DYMOLA® (Modelica) and SimulationX®

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



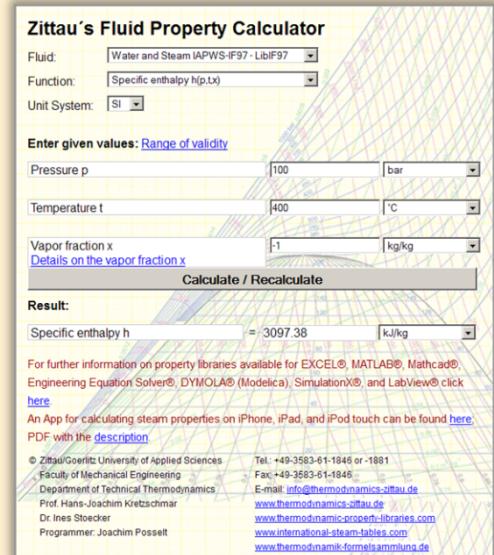
## Add-On FluidEES for Engineering Equation Solver®



## App International Steam Tables for iPhone, iPad, iPod touch, Android Smartphones and Tablets



## Online Property Calculator at [www.thermofluidprop.com](http://www.thermofluidprop.com)



## Property Software for Pocket Calculators

### FluidCasio



### FluidHP



### FluidTI



## For more information please contact:



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Prof. Dr. Hans-Joachim Kretzschmar  
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Email: [info@thermofluidprop.com](mailto:info@thermofluidprop.com)  
Phone: +49-351-27597860  
Mobile: +49-172-7914607  
Fax: +49-3222-1095810

The following thermodynamic and transport properties<sup>a</sup> 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  $\rho$
- Specific volume  $v$
- Enthalpy  $h$
- Internal energy  $u$
- Entropy  $s$
- Exergy  $e$
- Isobaric heat capacity  $c_p$
- Isochoric heat capacity  $c_v$
- Isentropic exponent  $\kappa$
- Speed of sound  $w$
- Surface tension  $\sigma$

### Transport Properties

- Dynamic viscosity  $\eta$
- Kinematic viscosity  $\nu$
- Thermal conductivity  $\lambda$
- Prandtl number  $Pr$
- Thermal diffusivity  $a$

### Backward Functions

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

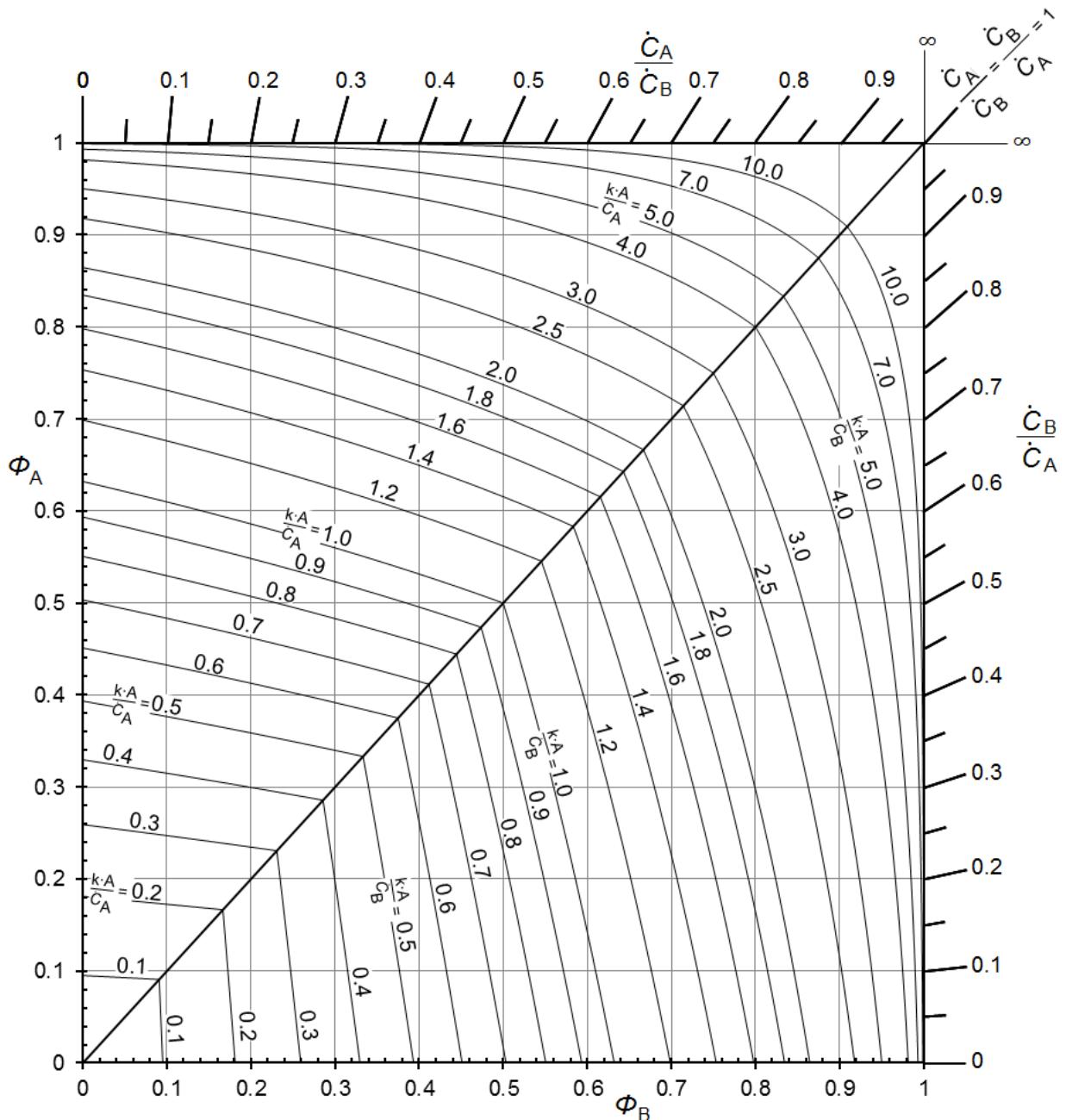
### Thermodynamic Derivatives

- Partial derivatives used in process modeling can be calculated.

<sup>a</sup> Not all of these property functions are available in all property libraries.

## 5. Diagrams of Dimensionless Temperature Changes

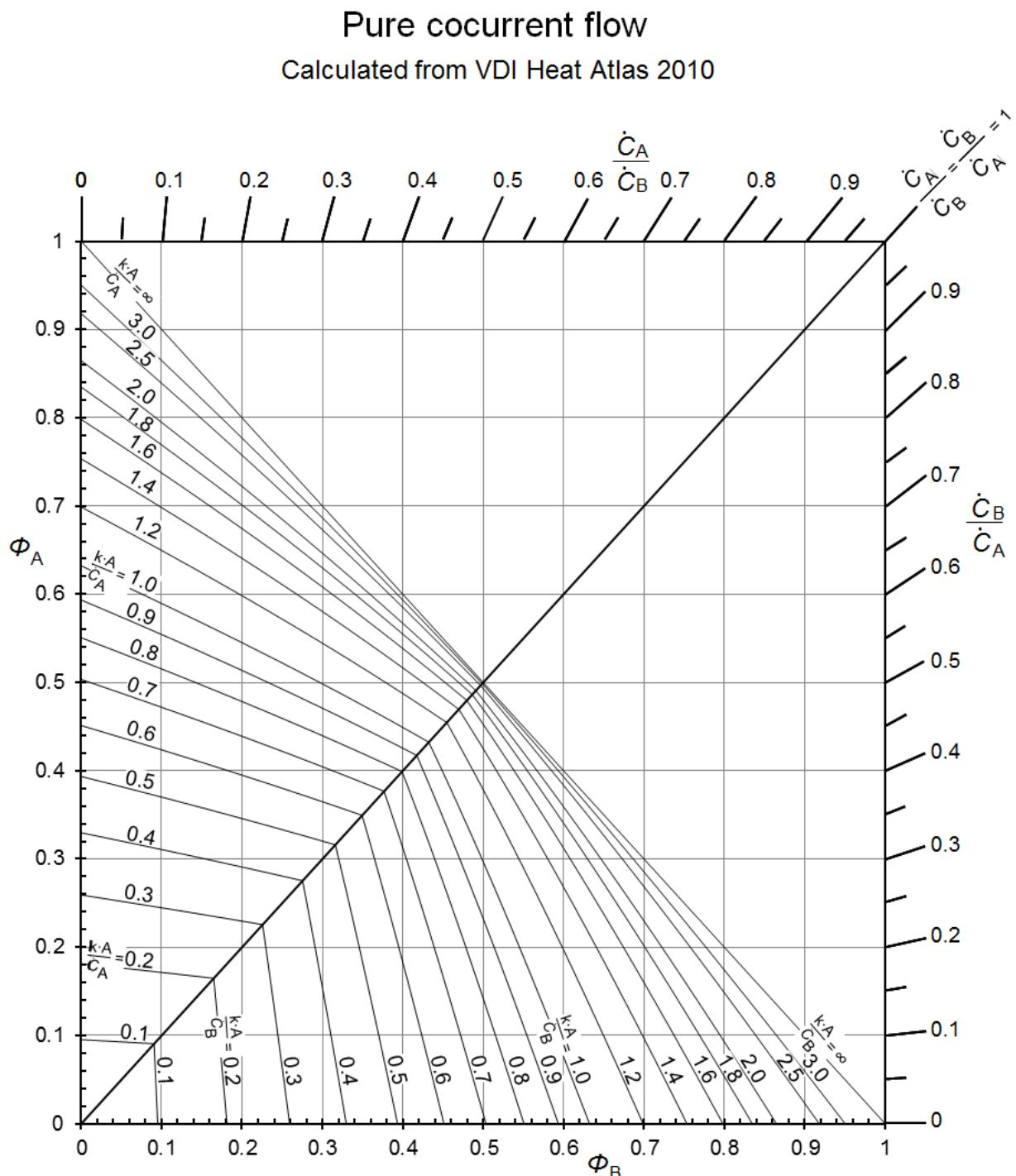
Pure counter current flow  
Calculated from VDI Heat Atlas 2010



Prepared by Guido Keuchel

Zittau/Goerlitz University of Applied Sciences  
Prof. Hans-Joachim Kretzschmar  
Dr. Ines Stoecker  
[www.thermodynamik-zittau.de](http://www.thermodynamik-zittau.de)

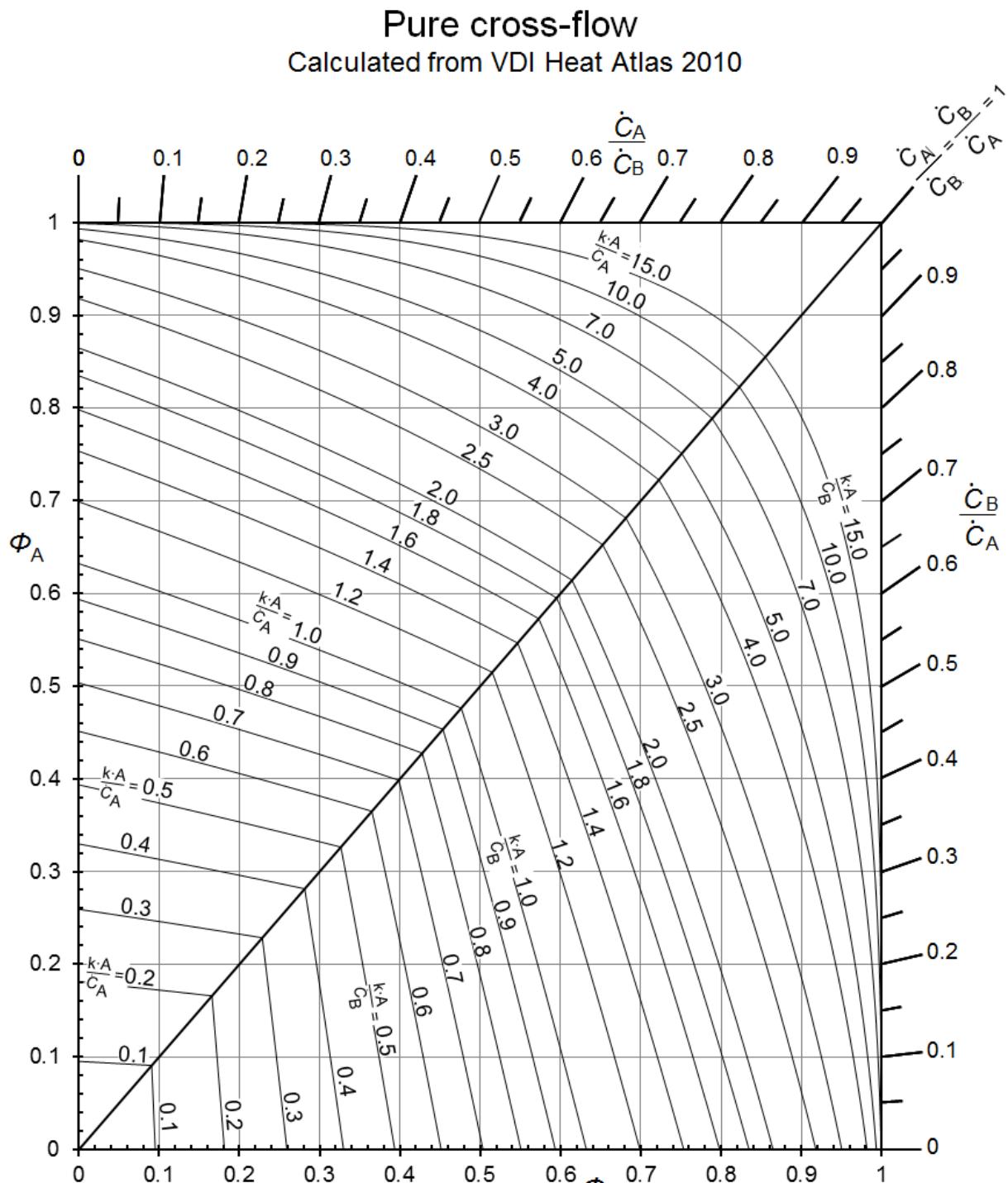
Figure 5.1: Pure counter current flow - ITYPE 1



Prepared by Guido Keuchel

Zittau/Goerlitz University of Applied Sciences  
Prof. Hans-Joachim Kretzschmar  
Dr. Ines Stoecker  
[www.thermodynamik-zittau.de](http://www.thermodynamik-zittau.de)

**Figure 5.2: Pure cocurrent flow - ITYPE 2**



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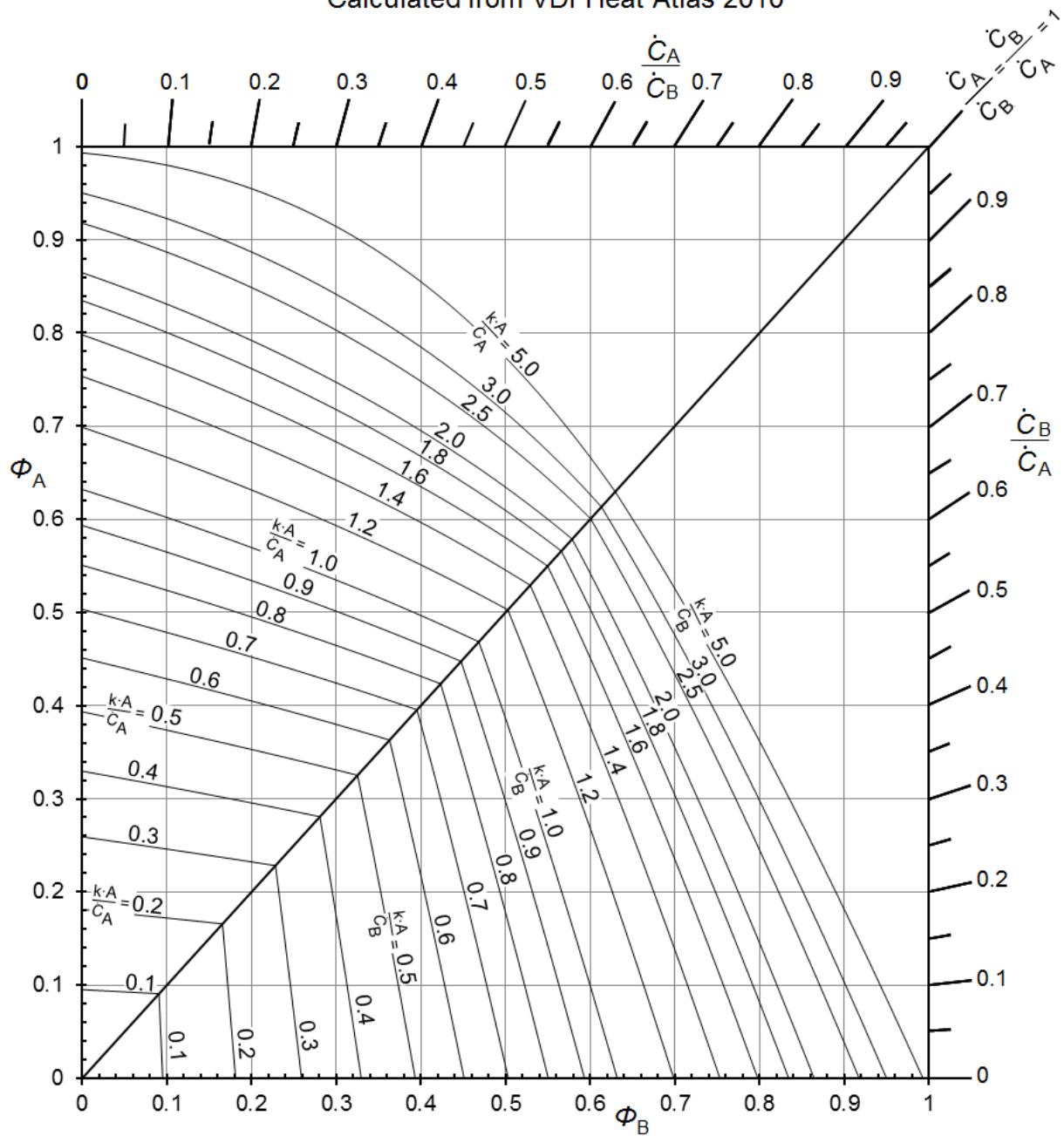
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**Figure 5.3: Pure cross-flow - ITYPE 3**

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



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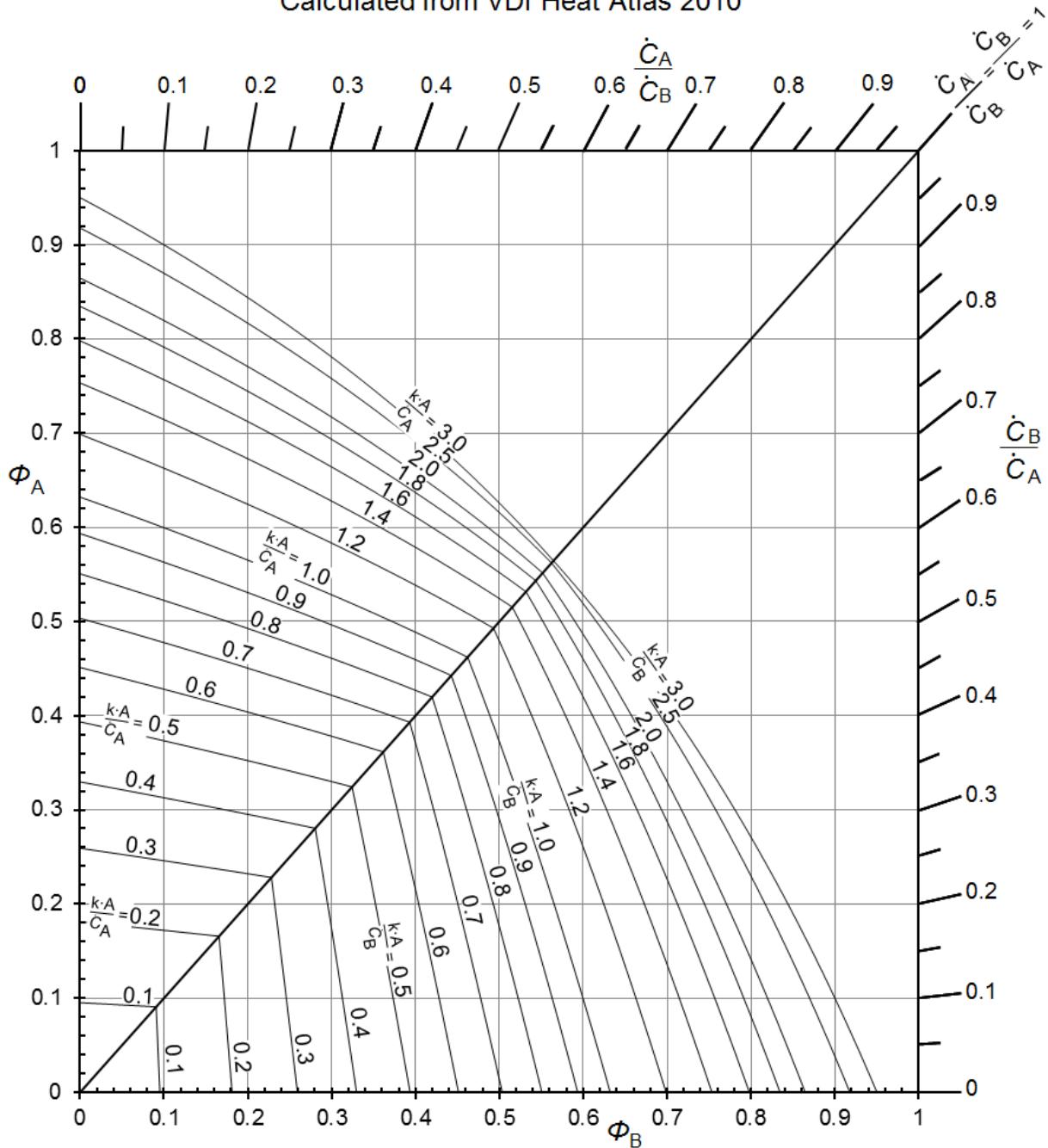
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**Figure 5.4: Cross-flow with one tube row, laterally mixed on one side - ITYPE 4**

## Cross-flow, laterally mixed on both sides

Calculated from VDI Heat Atlas 2010

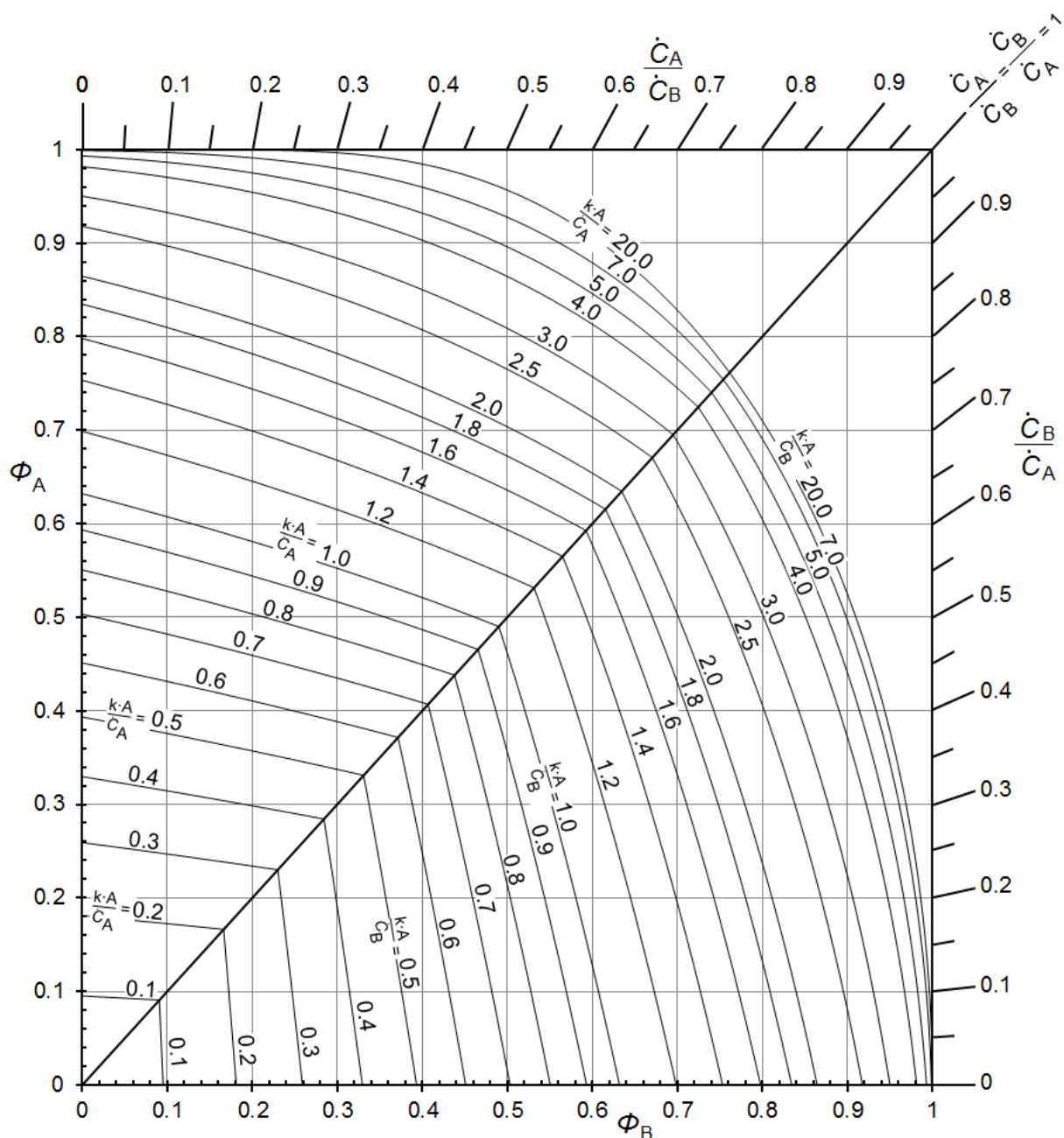


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**Figure 5.5: Cross-flow, laterally mixed on both sides - ITYPE 5**

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



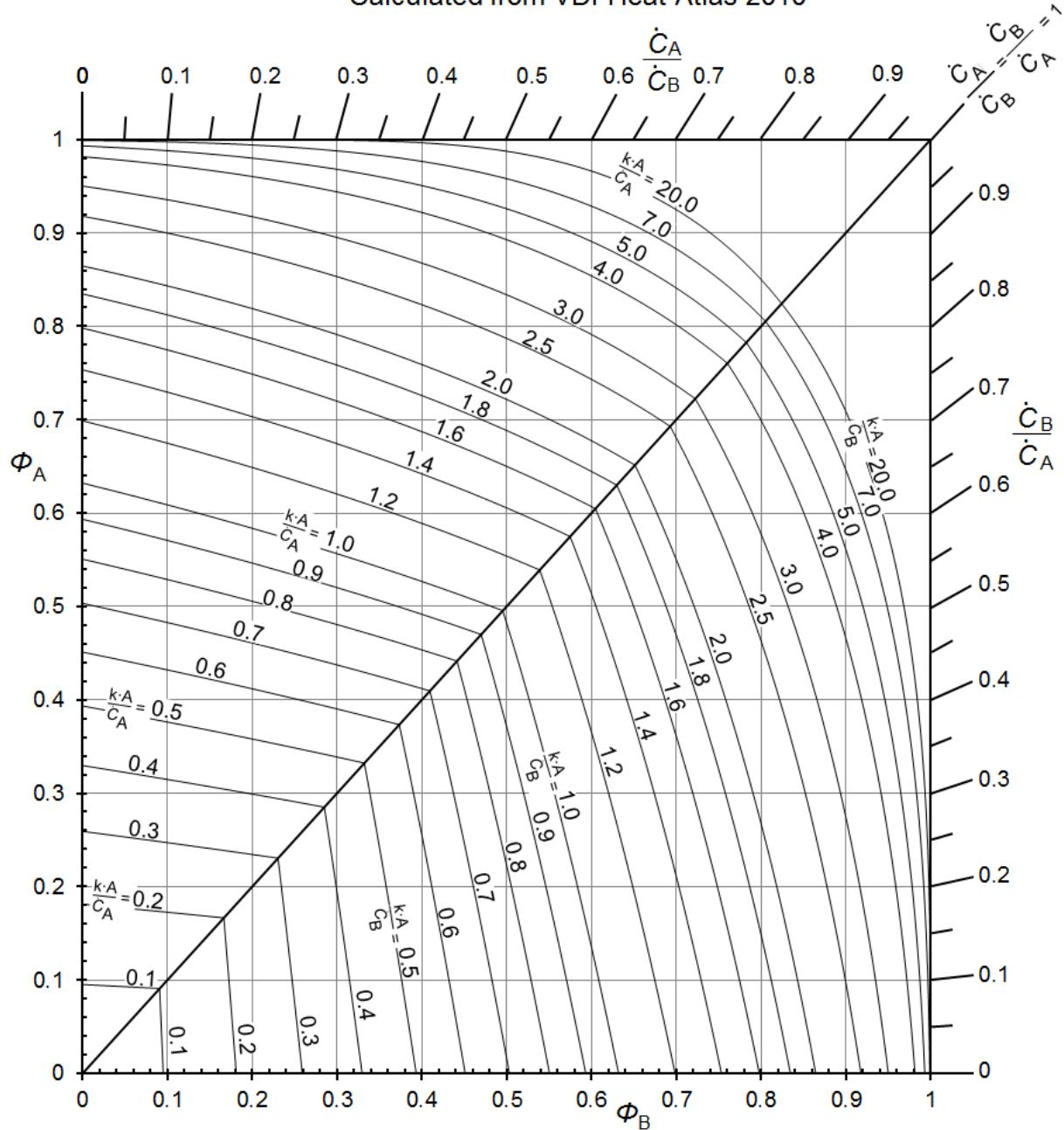
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**Figure 5.6: Counterdirected countercurrent cross-flow with two tube rows and two passes - ITYPE 6**

## Counterdirected countercurrent cross-flow with three tube rows and three passes

Calculated from VDI Heat Atlas 2010

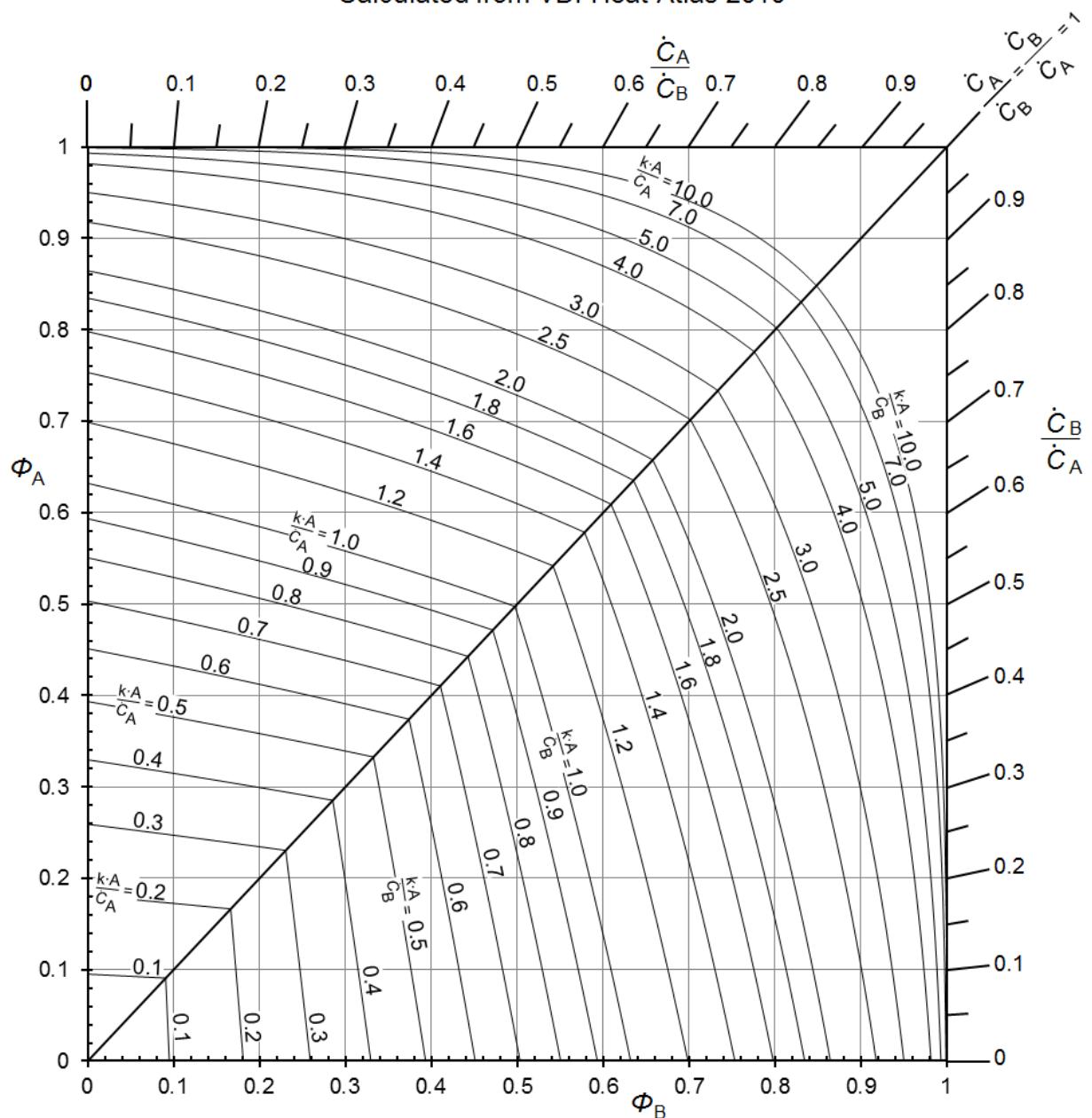


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**Figure 5.7: Counterdirected countercurrent cross-flow with three tube rows and three passes - ITYPE 7**

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



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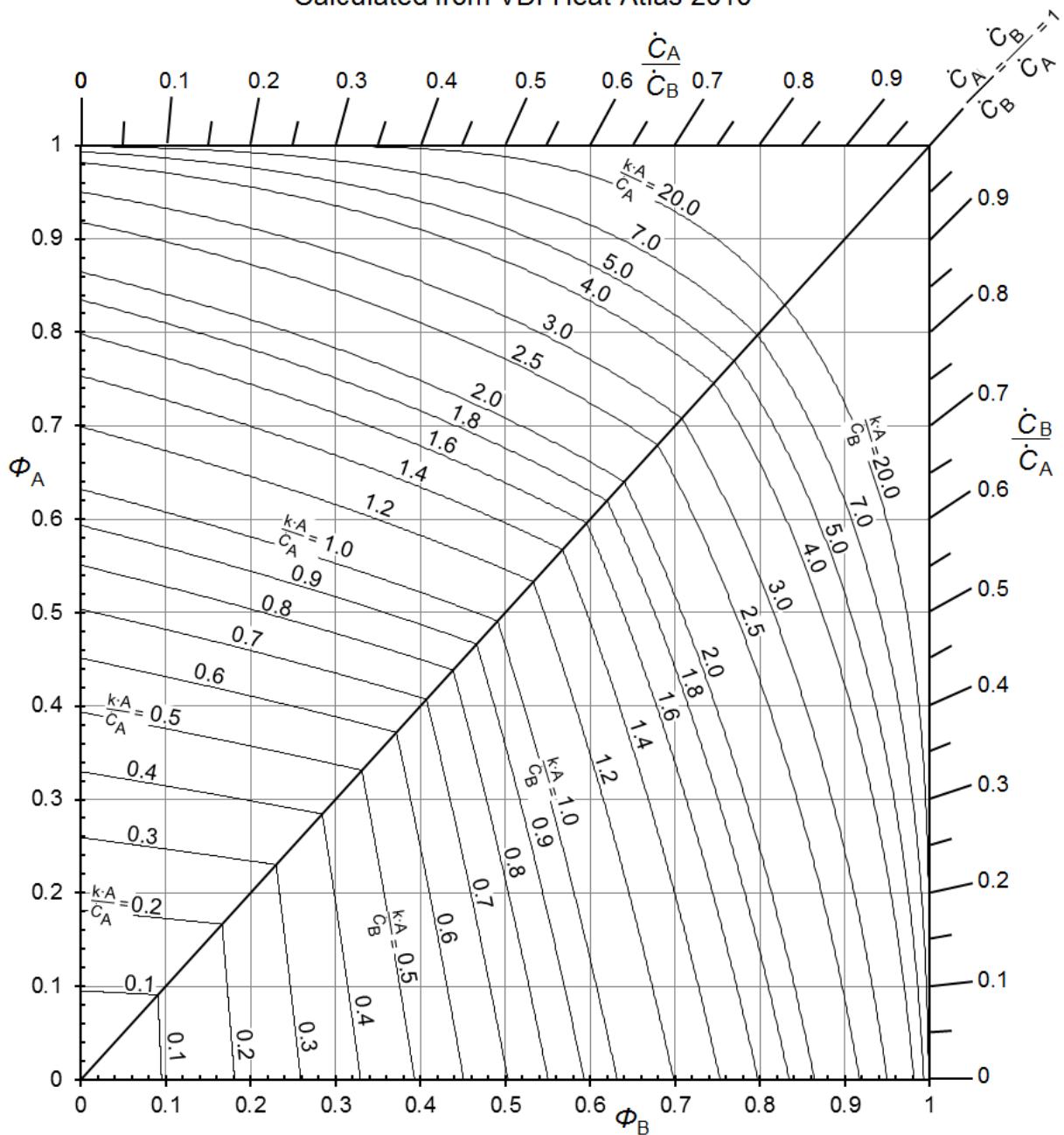
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**Figure 5.8: Counterdirected countercurrent cross-flow with four tube rows and four passes - ITYPE 8**

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



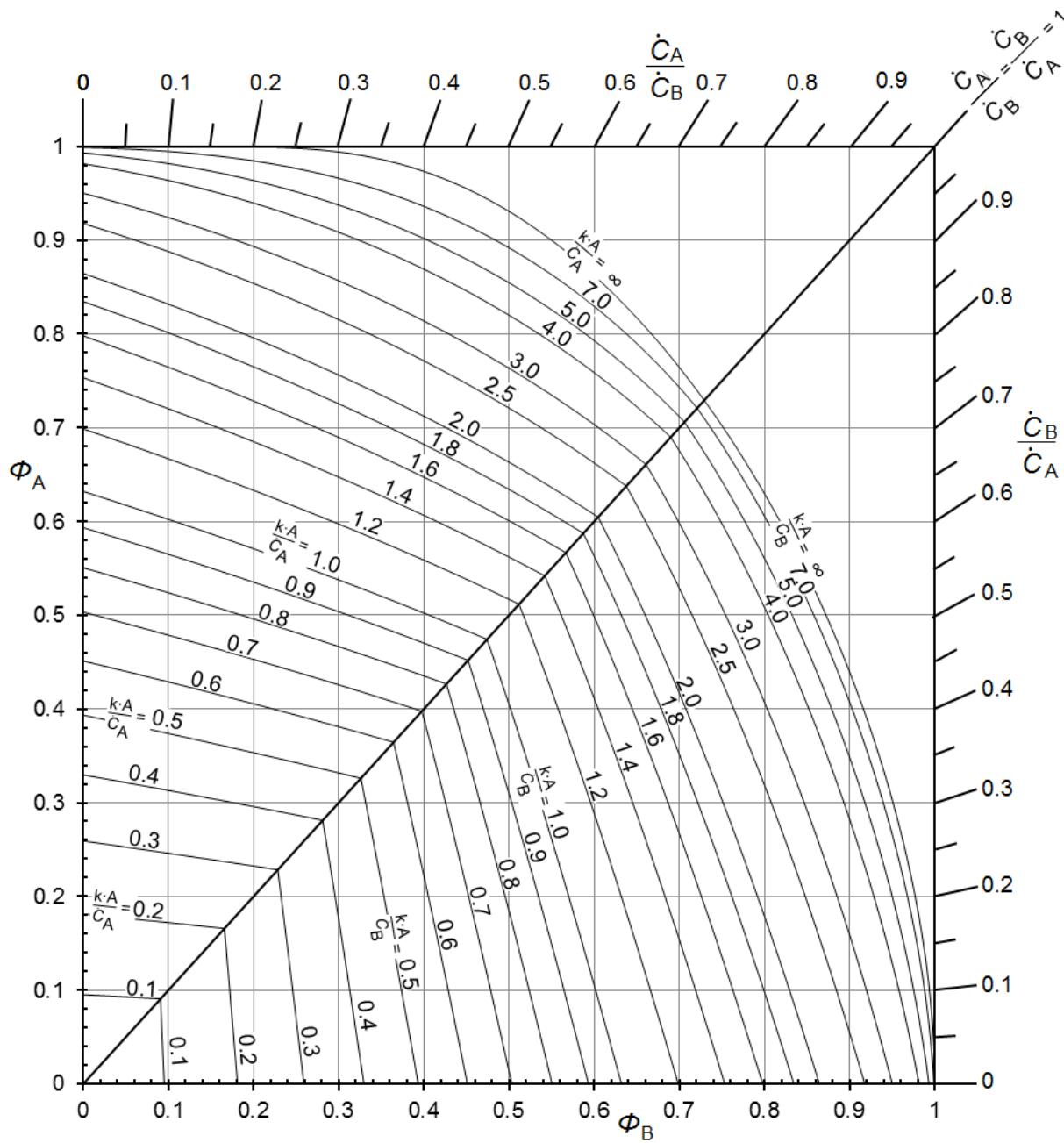
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**Figure 5.9: Countercurrent-cross flow with four tube rows and two passes - ITYPE 9**

## Cross-flow with two tube rows and one pass

Calculated from VDI Heat Atlas 2010



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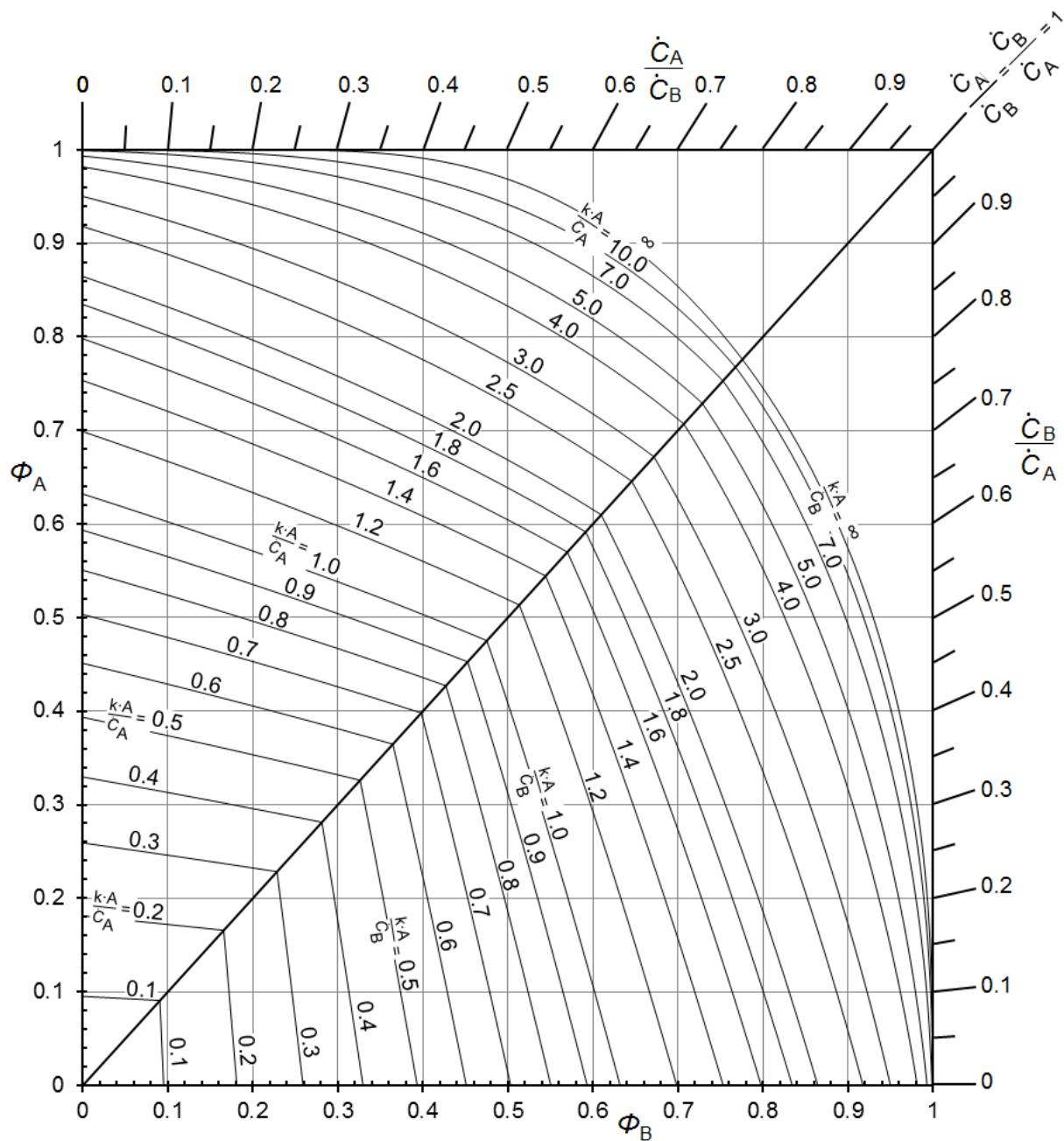
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Figure 5.10: Cross-flow with two tube rows and one pass - ITYPE 10 and NSPEC 2

## Cross-flow with three tube rows and one pass

Calculated from VDI Heat Atlas 2010



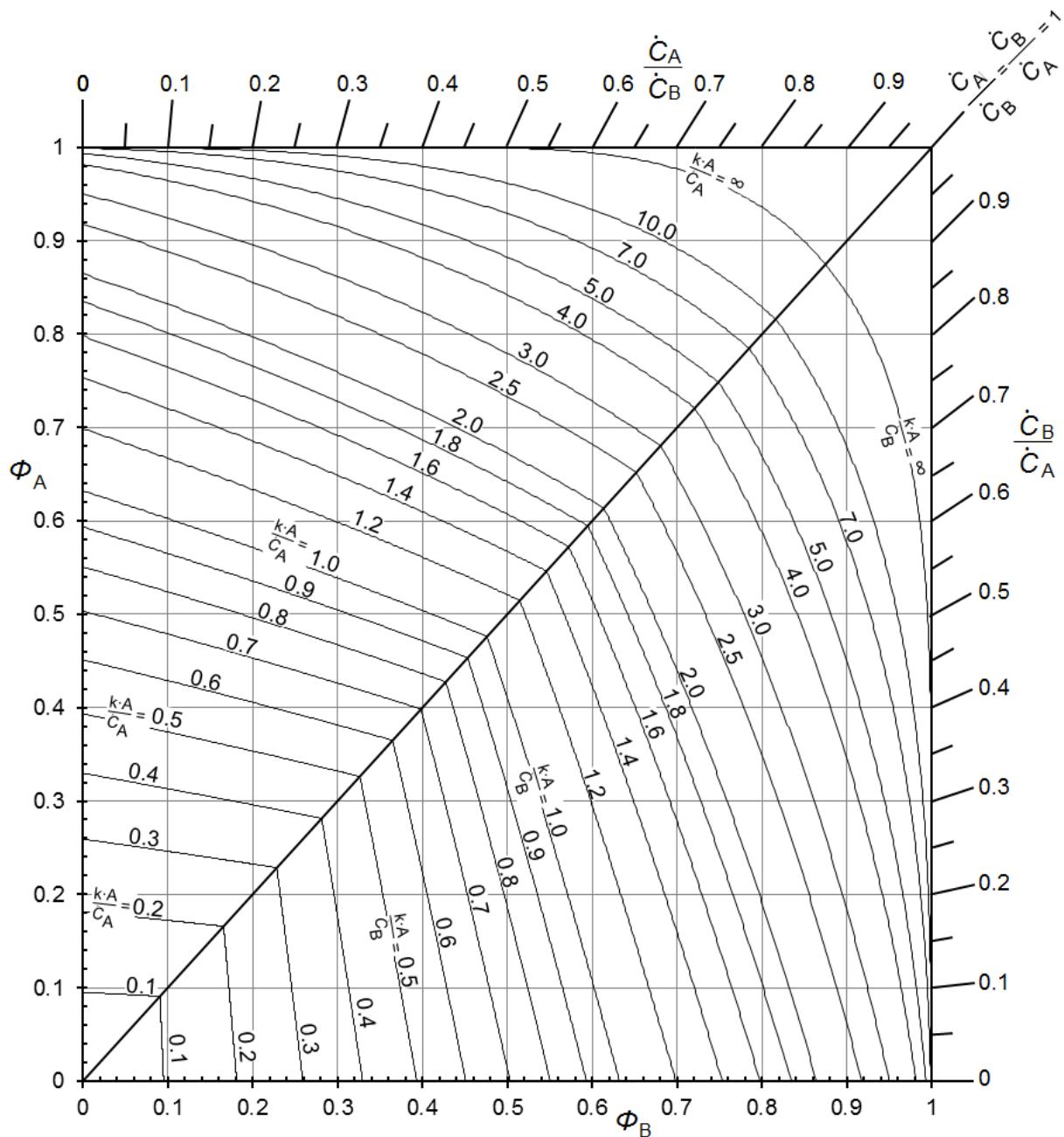
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Figure 5.11: Cross-flow with three tube rows and one pass - ITYPE 10 and NSPEC 3

## Cross-flow with ten tube rows and one pass

Calculated from VDI Heat Atlas 2010



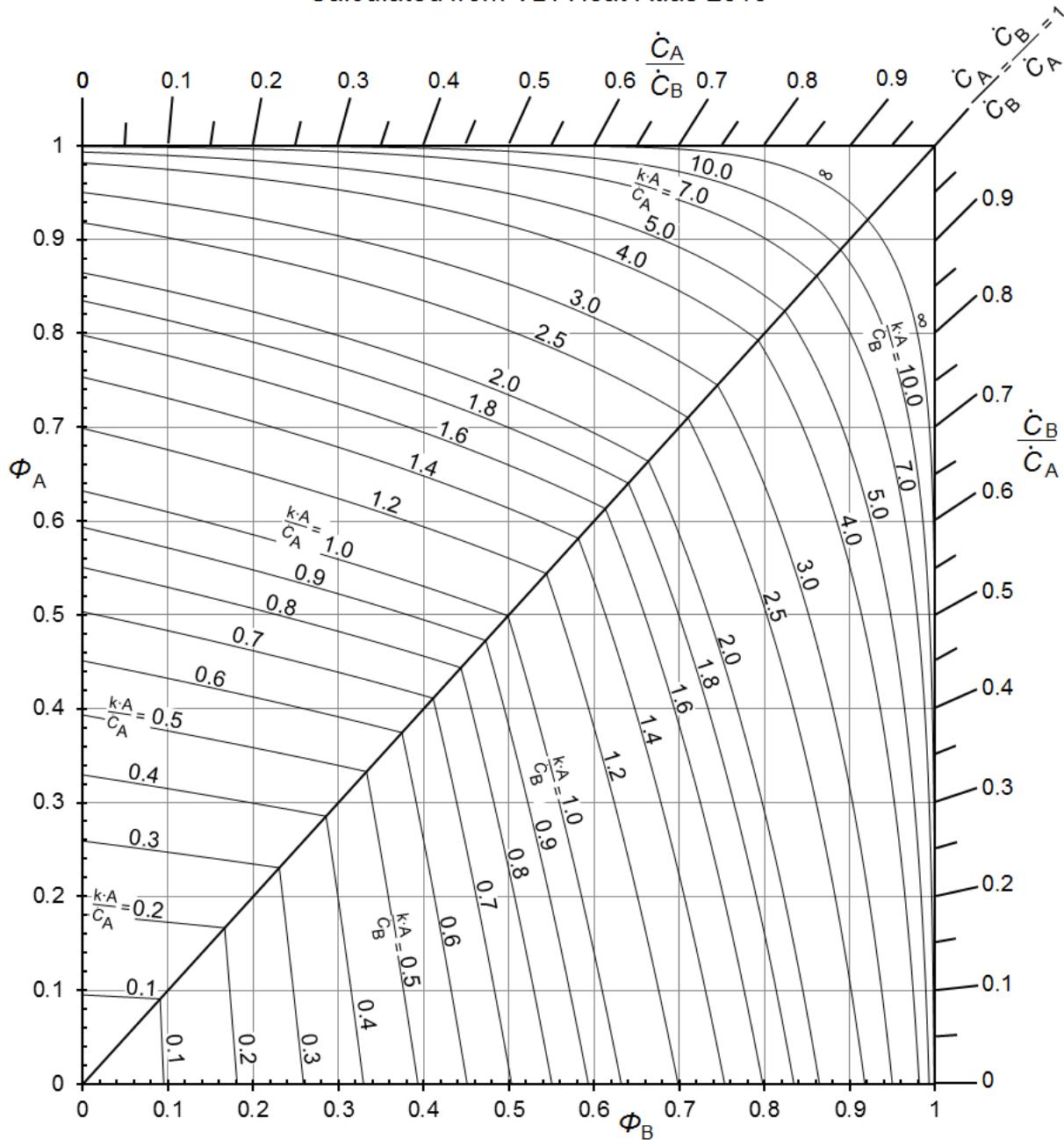
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Figure 5.12: Cross-flow with ten tube rows and one pass - ITYPE 10 and NSPEC 10

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

Calculated from VDI Heat Atlas 2010



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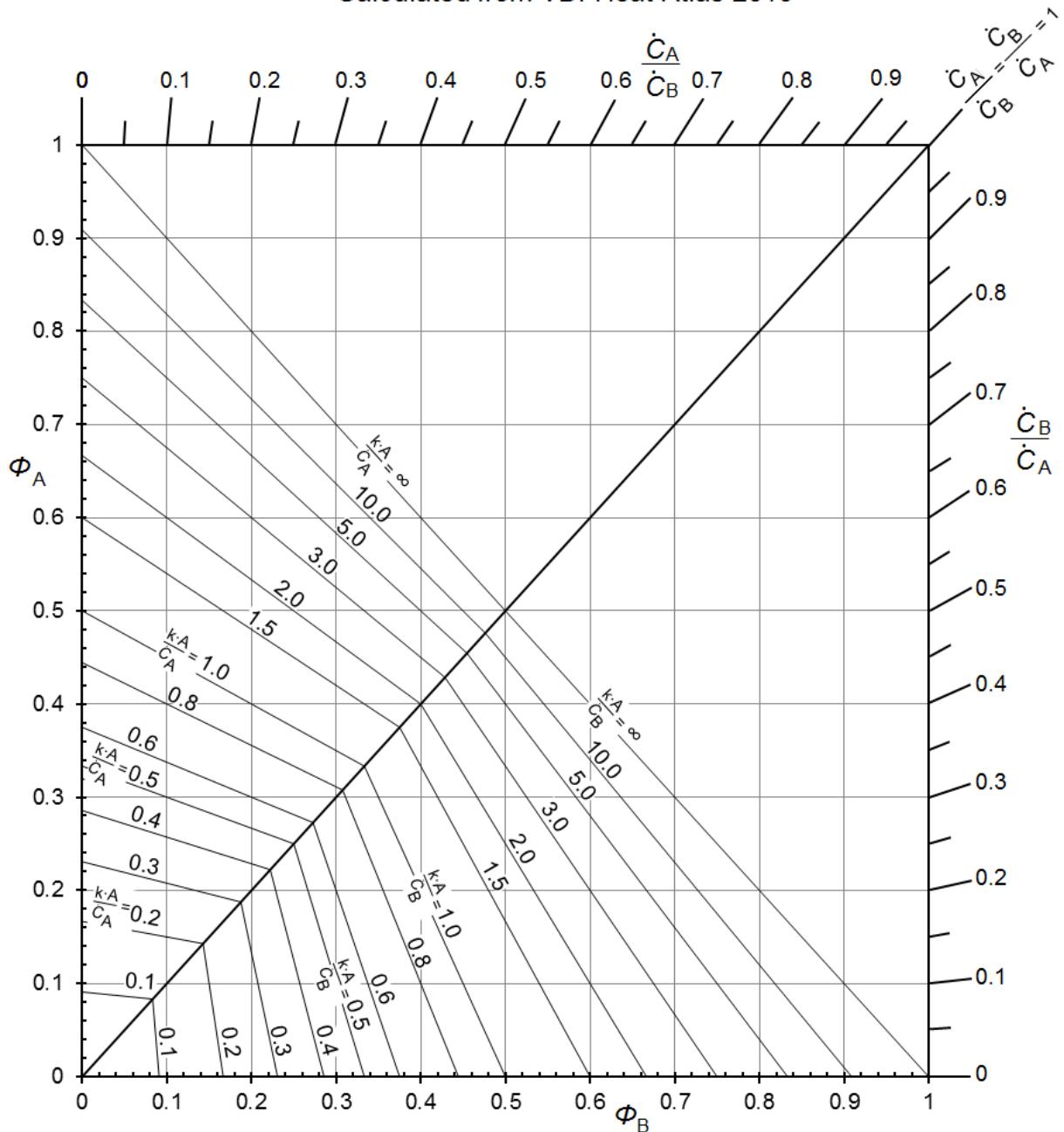
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**Figure 5.13: Codirected countercurrent cross-flow with six tube rows and six passes - ITYPE 11 and NSPEC 6**

Two-sided stirred tank  
Calculated from VDI Heat Atlas 2010

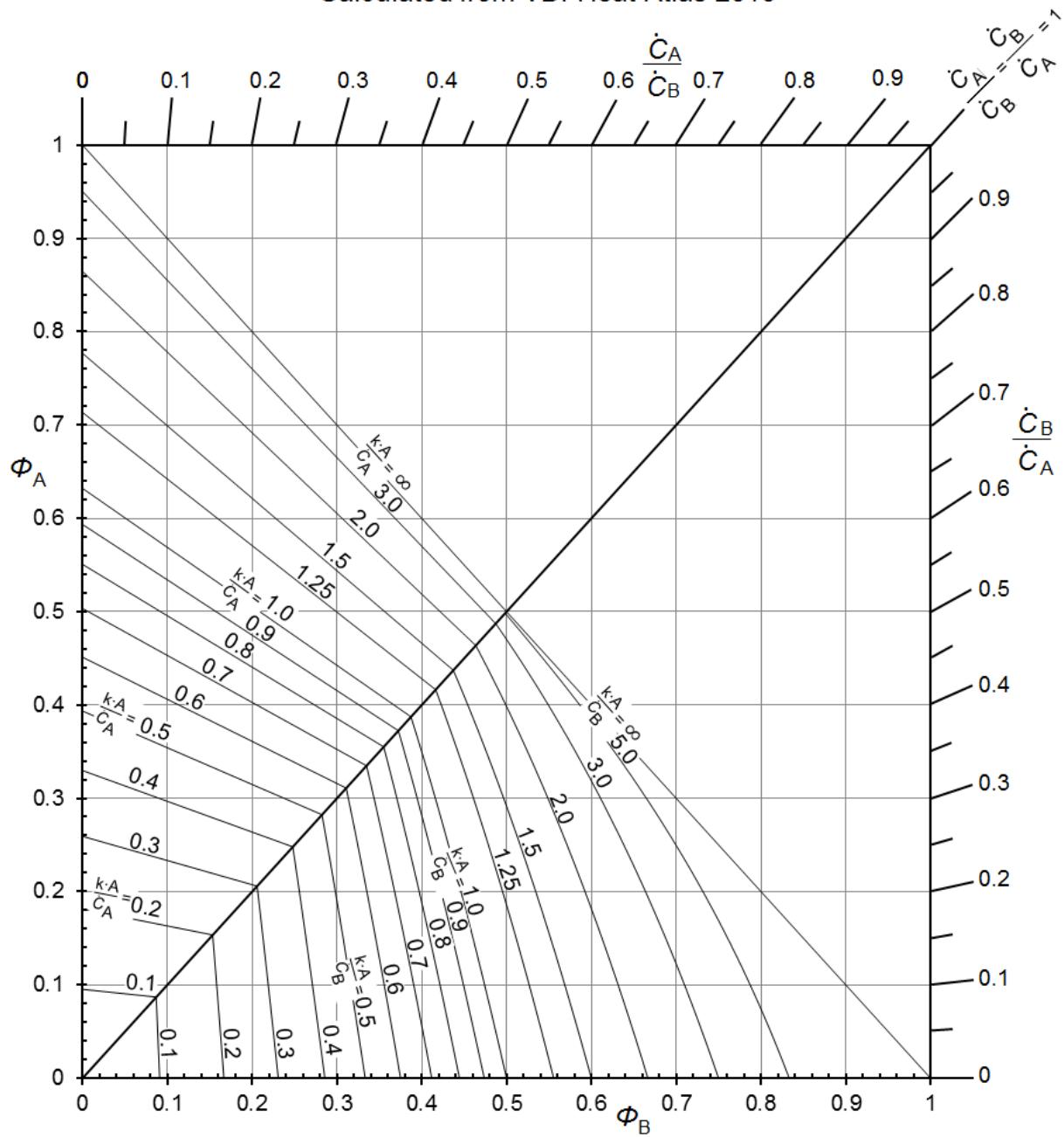


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**Figure 5.14: Two-sided stirred tank - ITYPE 12**

**One-sided stirred tank**  
Calculated from VDI Heat Atlas 2010



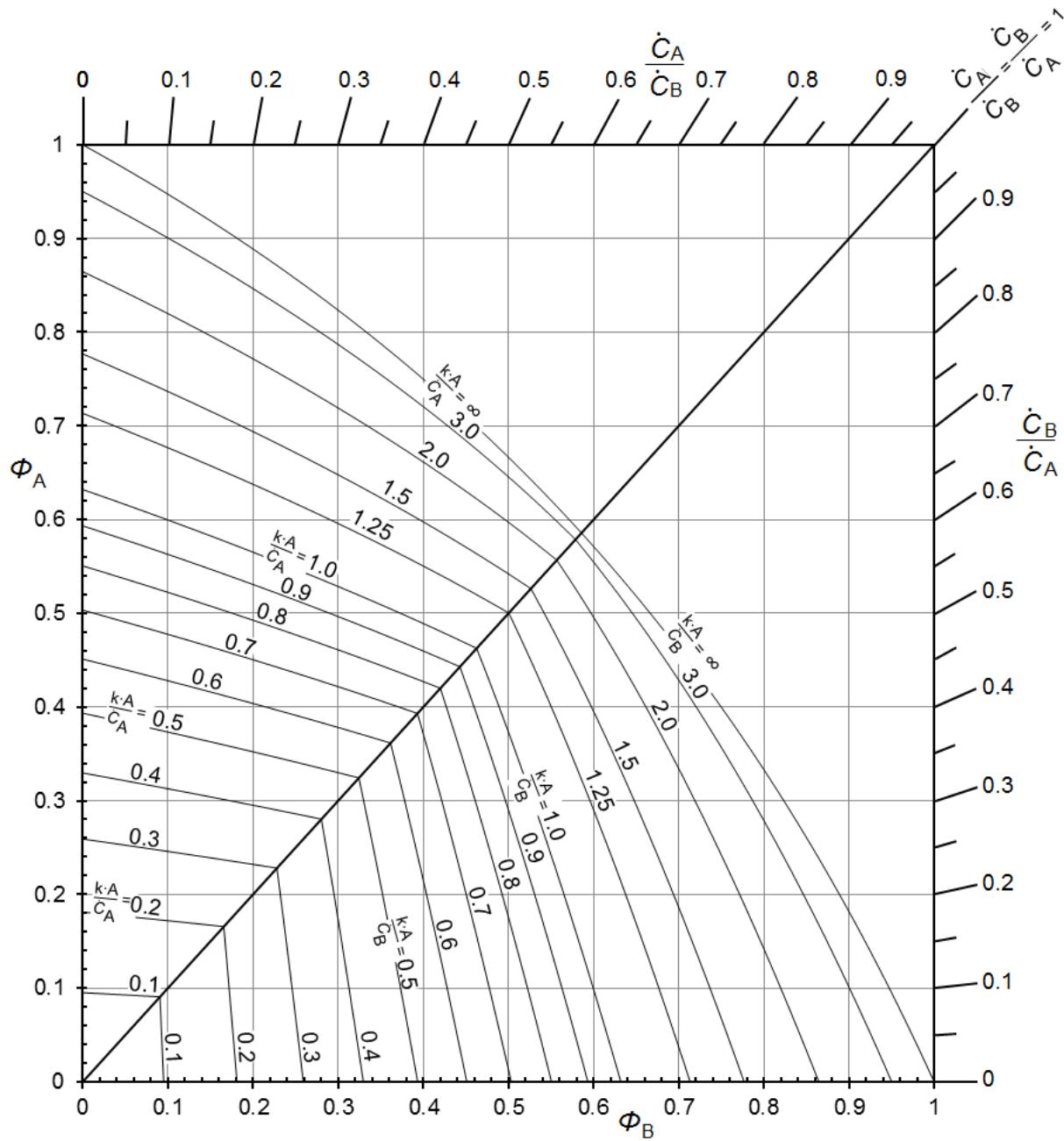
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**Figure 5.15: One-sided stirred tank - ITYPE 13**

## One shell-side and two tube-side passes

Calculated from VDI Heat Atlas 2010

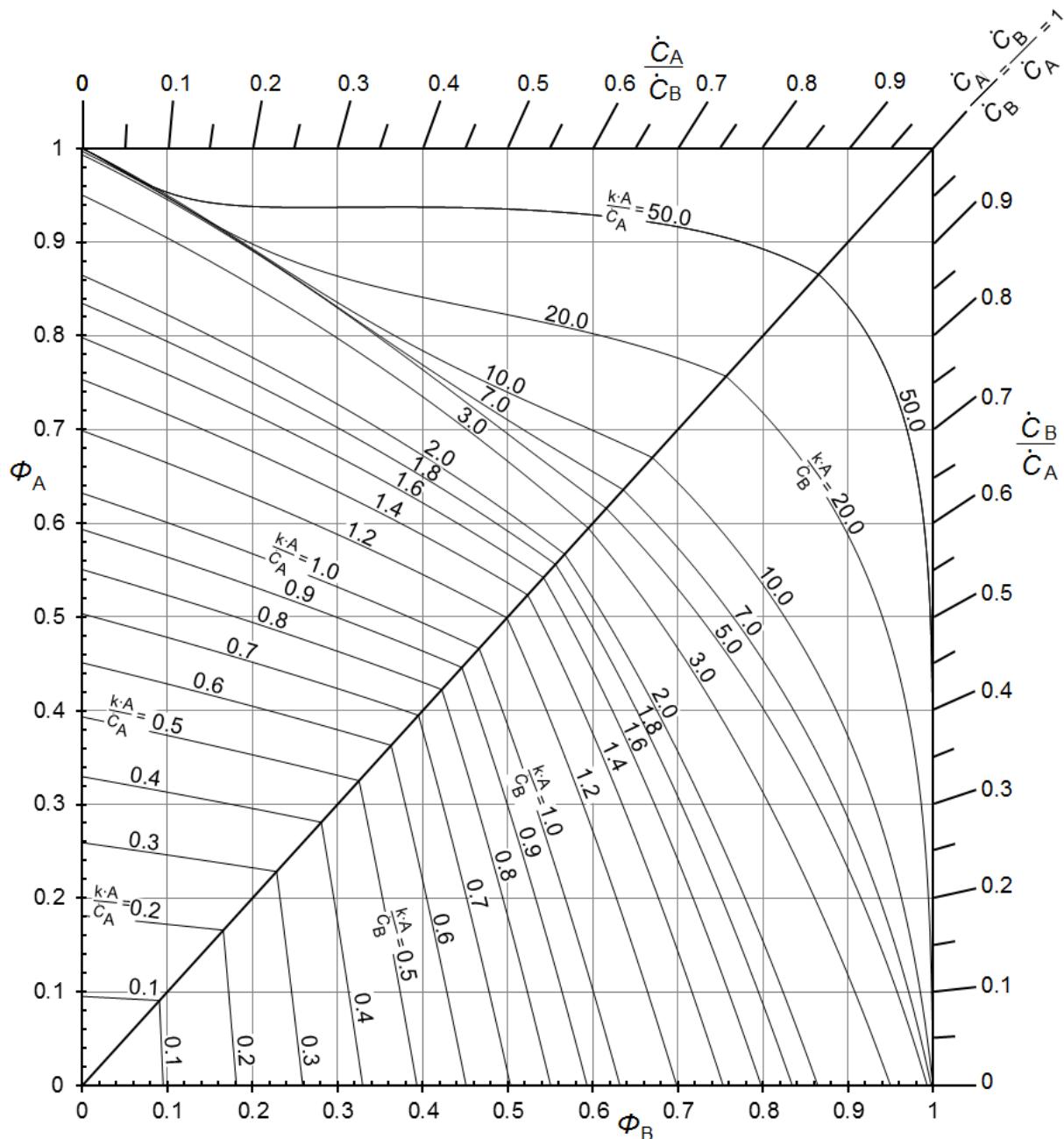


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**Figure 5.16: One shell-side and two tube-side passes - ITYPE 14**

**One shell-side and three tubeside passes,  
two countercurrent**  
Calculated from VDI Heat Atlas 2010

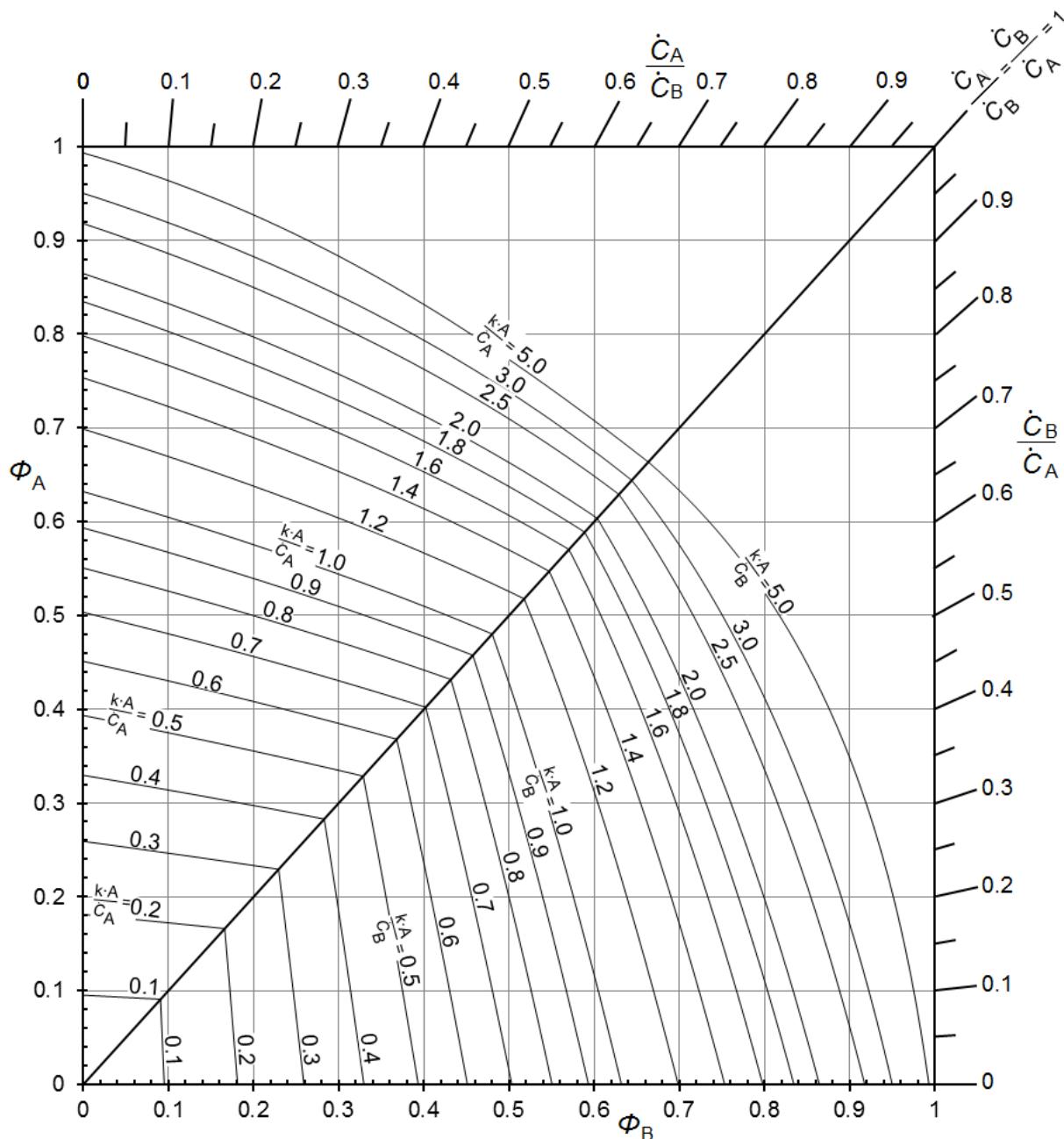


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**Figure 5.17: One shell-side and three tube-side passes, two countercurrent - ITYPE 15**

**One shell-side and two tubeside passes,  
both countercurrent**  
Calculated from VDI Heat Atlas 2010

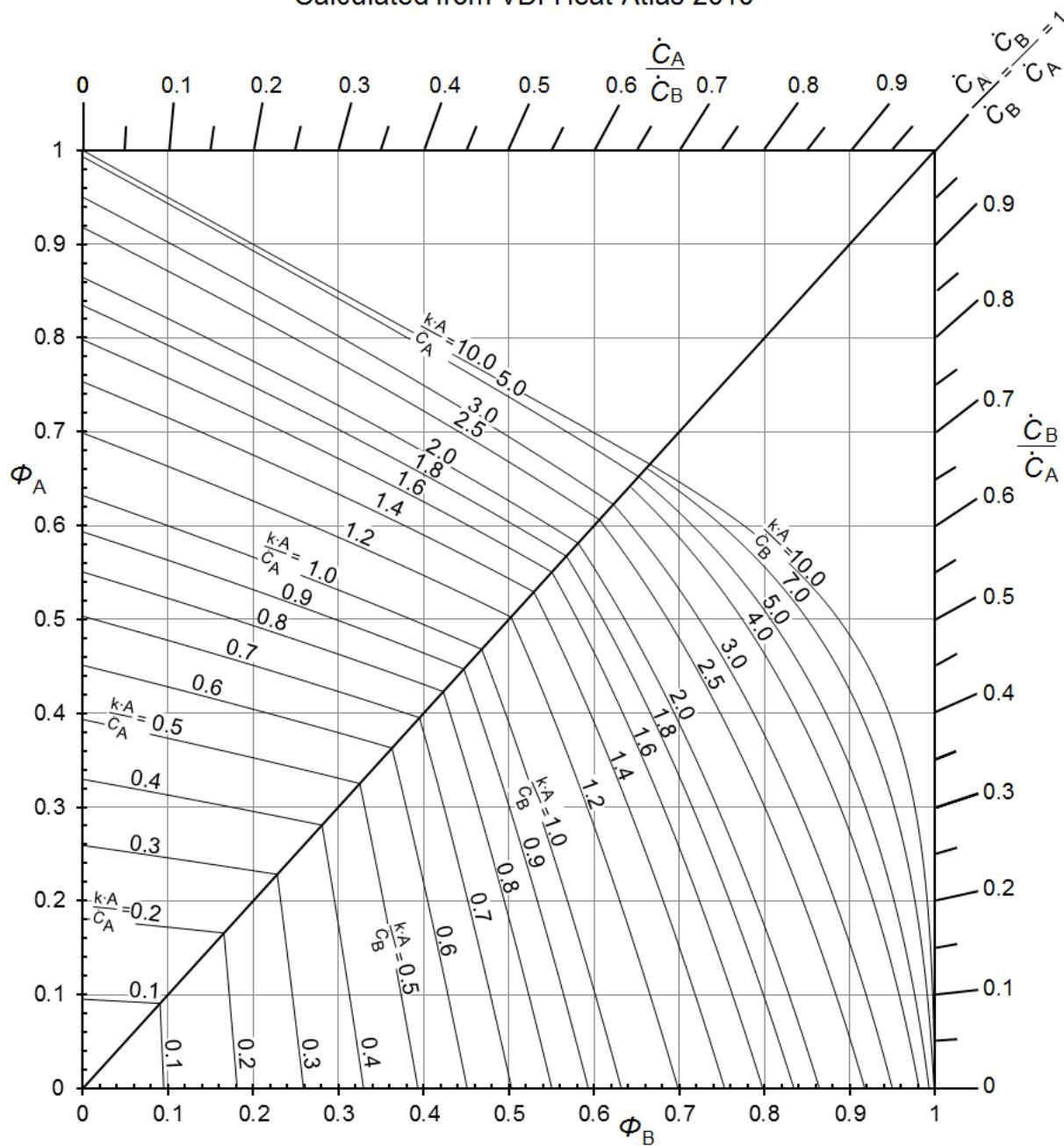


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**Figure 5.18: One shell-side and two tube-side passes, both countercurrent - ITYPE 16**

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

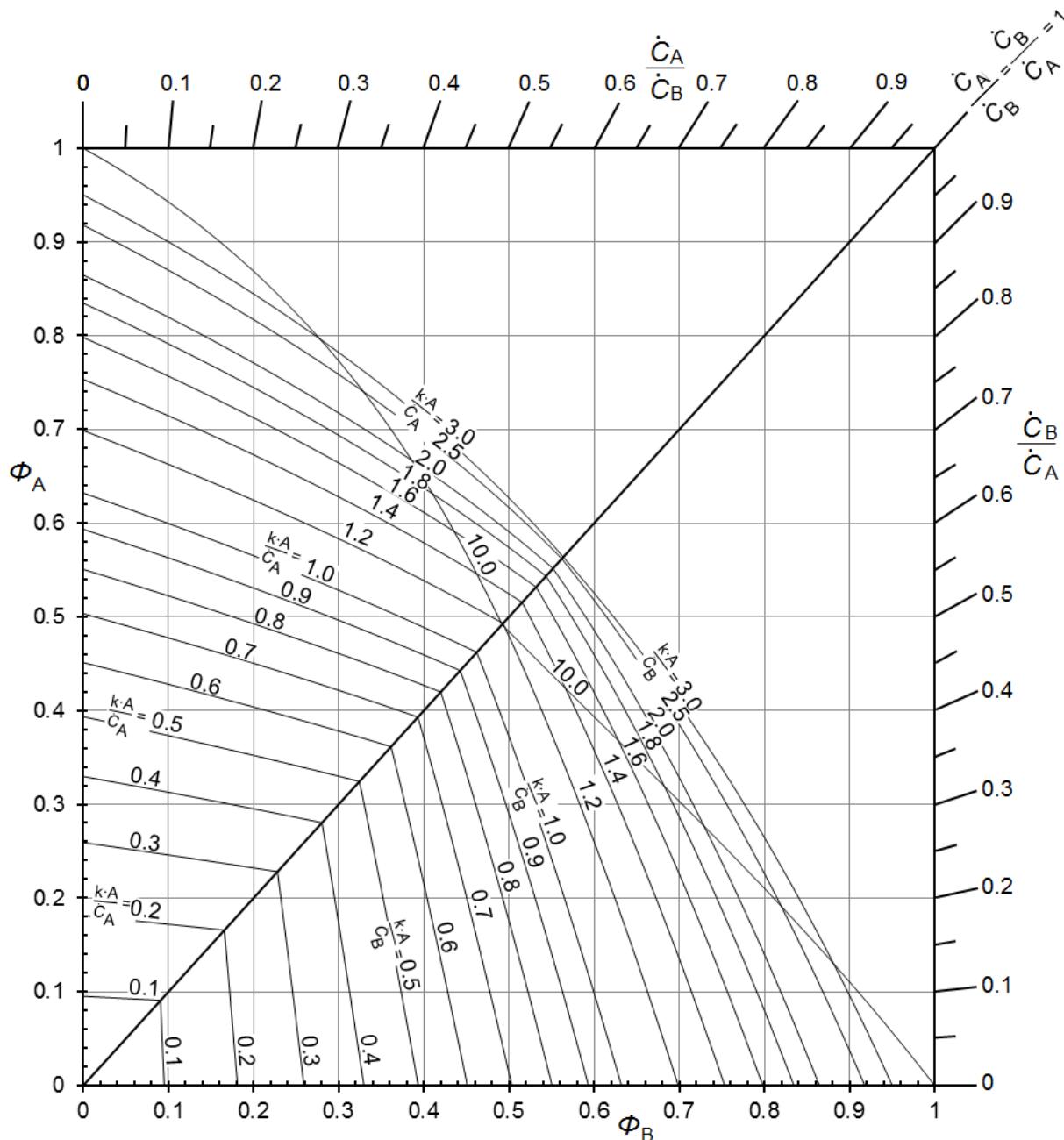


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Figure 5.19: Divided flow with one shellside and one tube-side pass - ITYPE 17

**Divided flow with one shell-side and  
two tube-side passes**  
Calculated from VDI Heat Atlas 2010



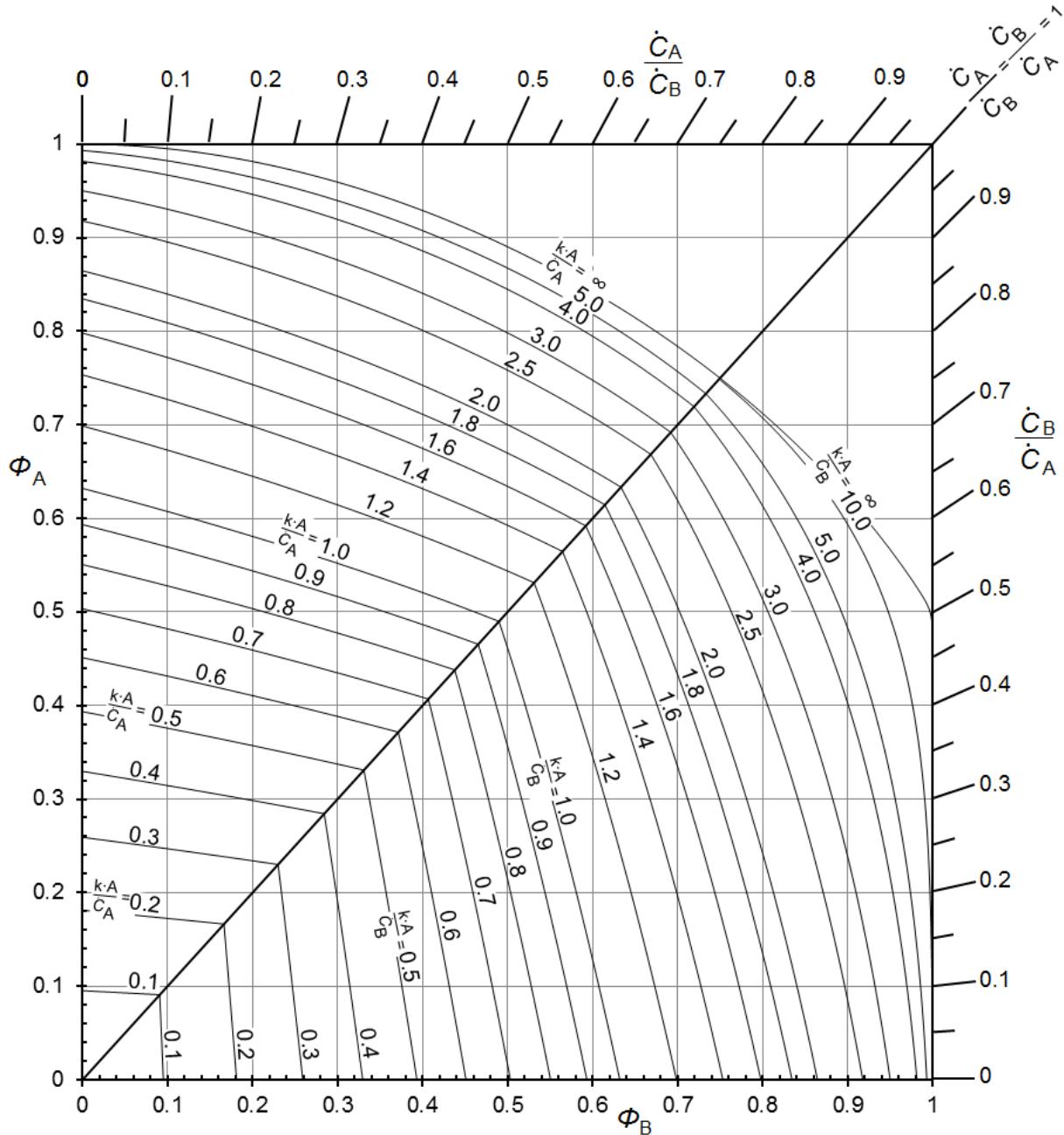
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**Figure 5.20: Divided flow with one shell-side and two tube-side passes - ITYPE 18**

**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



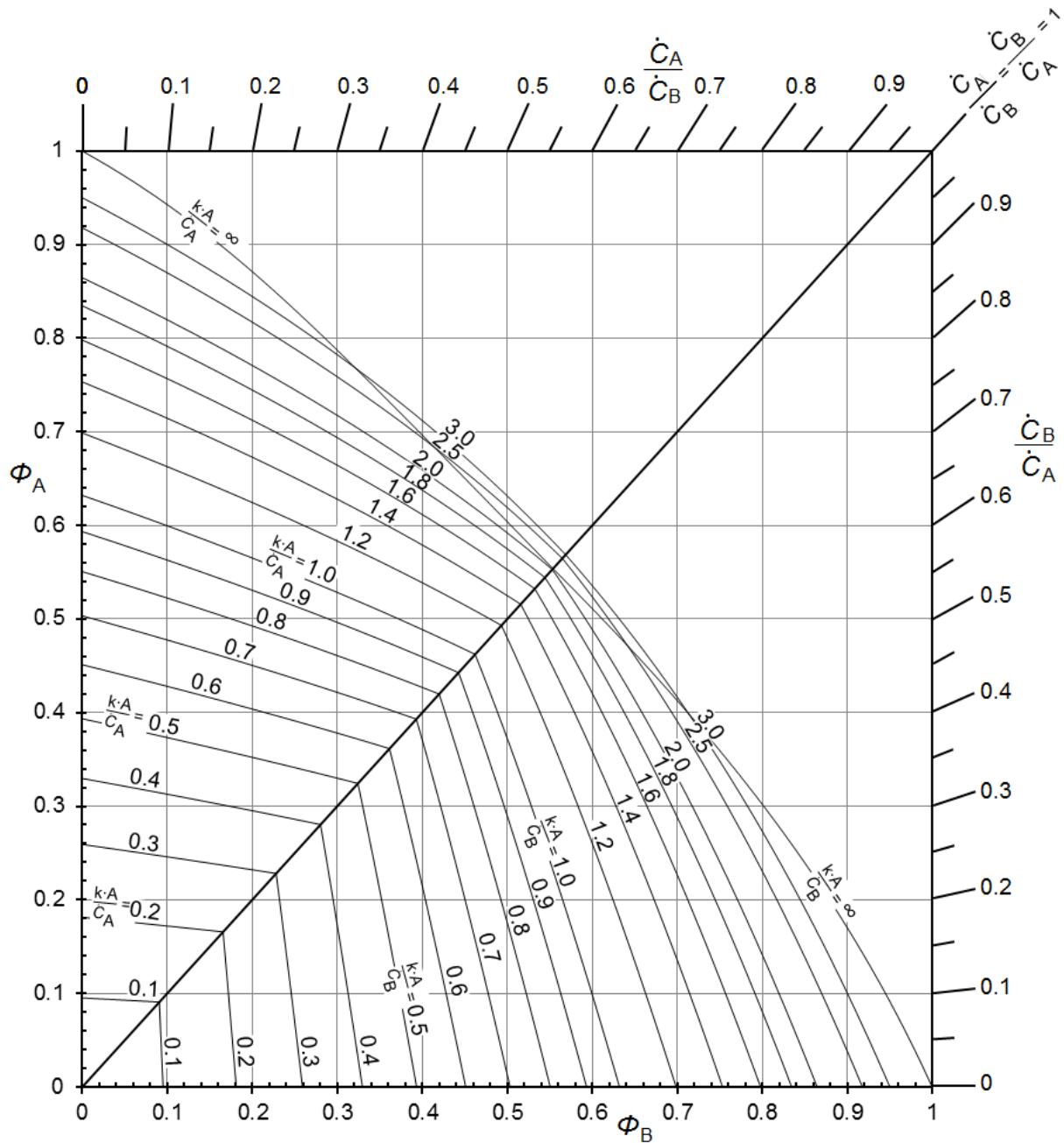
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**Figure 5.21: Split flow with longitudinal baffle and two shell-side and two tube-side passes (tube-side outlet and shell-side inlet on the same side) - ITYPE 19**

## One shell-side and four tube-side passes

Calculated from VDI Heat Atlas 2010

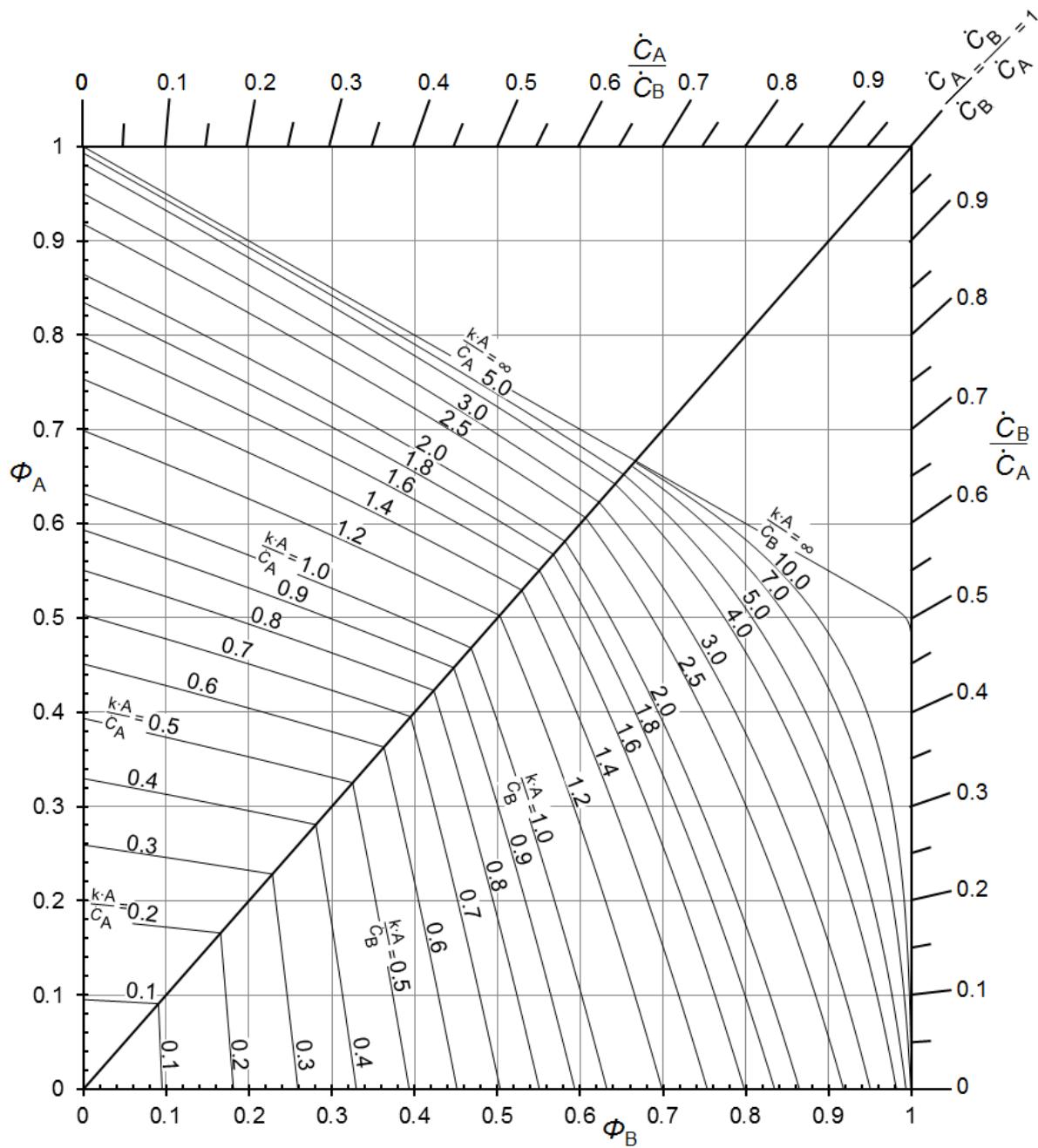


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**Figure 5.22: One shell-side and four tube-side passes - ITYPE 20 and NSPEC 2**

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

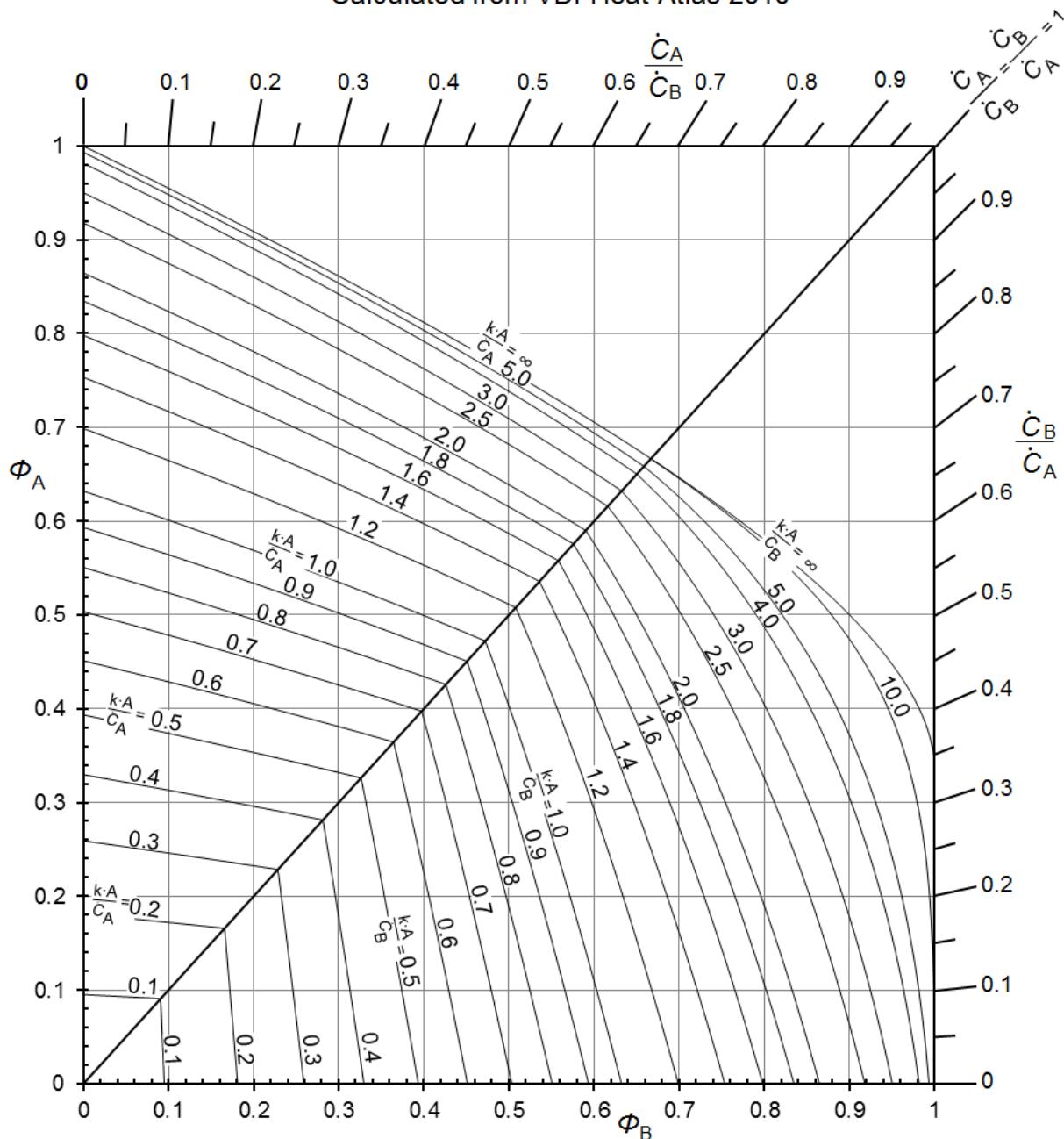


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 Bearbeitet von Dipl.-Ing. (FH) G. Keuchel

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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



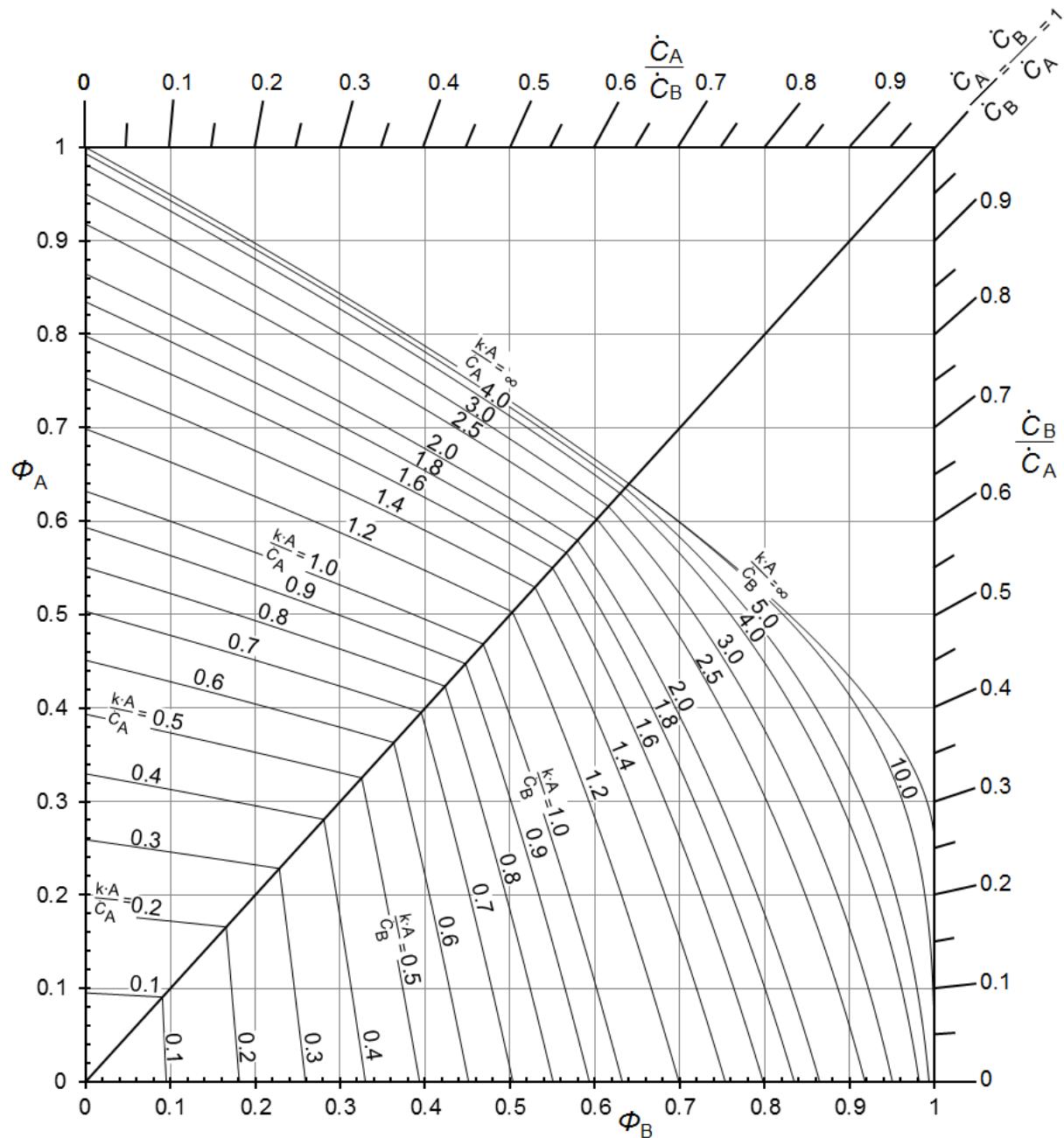
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**Figure 5.24: One pass for stream 1 and three passes for stream 2,  
two in countercurrent - ITYPE 22**

## One pass for stream 1 and four passes for stream 2

Calculated from VDI Heat Atlas 2010

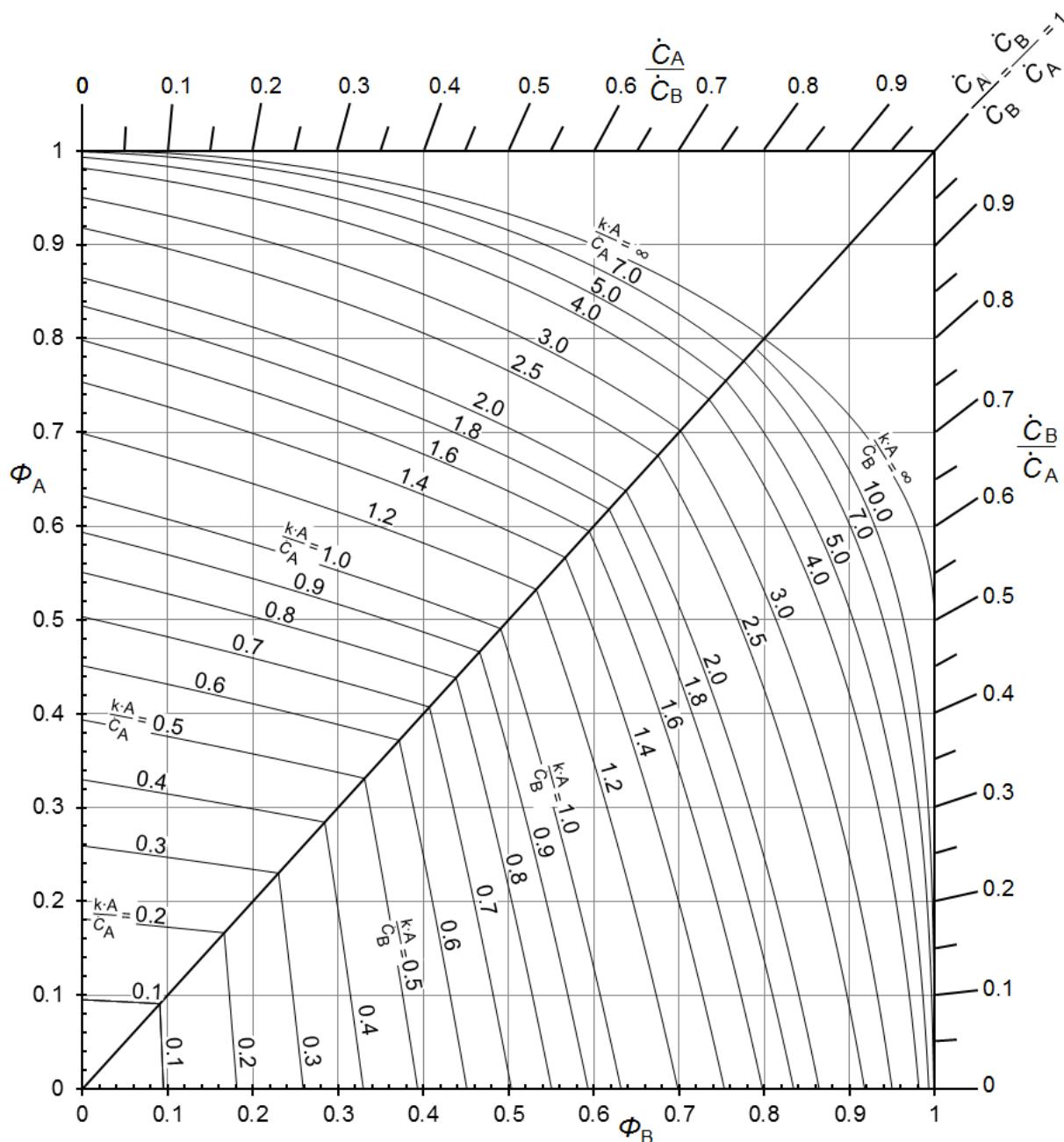


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**Figure 5.25: One pass for stream 1 and four passes for stream 2 - ITYPE 23**

**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**

## 6. Satisfied Customers

Period from 2018 to 2022

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- FluidEXL *Graphics* for Excel® incl. VBA
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- FluidMAT for Mathcad®
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- FluidVIEW for LabVIEW™
- FluidPYT for Python
- FluidJAVA for Java
- DLLs for Windows Applications
- Shared Objects for Linux
- Shared Objects for macOS.

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Wandschneider + Gutjahr, Hamburg	
RWE Supply & Trading, Essen	11/2022
Stadtwerke Rosenheim	
CEA, Saclay, France	10/2022
RWE Supply & Trading, Essen	
SEEC Saudi Energy Efficiency Center, Riyadh, Saudi Arabia	
MAN, Copenhagen, Denmark	
Hermeler & Partner Consulting Engineers, Sassenberg	09/2022
Envi Con, Nürnberg	
Drill Cool Systems, Bakersfield CA, USA	
RWE Supply & Trading, Essen	
Maerz Ofenbau, Zürich, Switzerland	
Saale Energie, Schkopau	
ERGO, Dresden	
Mainova, Frankfurt/Main	
Bundeswehr, Koblenz	08/2022
RWE Supply & Trading, Essen	
Grenzebach Corporation, Newnan GE, USA	
AGRANA, Gmuend, Austria	07/2022
MIBRAG, Zeitz	
Hochschule Niederrhein, Krefeld	
ULT, Löbau	06/2022
LEAG, Cottbus	
VPC Group, Vetschau	

Wärme, Hamburg	
ILK, Dresden	
Stricker IB, Küssnacht a. Rigi, Switzerland	
LEAG, Cottbus	05/2022
RWE Supply & Trading, Essen	
IGT Tomalla, Kreuztal	
B+T Engineering, Dübendorf, Switzerland	
Stricker IB, Küssnacht a. Rigi, Switzerland	
Vogelsang & Benning, Bochum	04/2022
Frischli, Rehburg-Loccum	
BPS Consulting, Sprenge	03/2022
HS Hannover, Maschinenbau & BioVT	
M+M Turbinentechnik, Bad Salzuflen	
Uni. Strathclyde, Glasgow, UK	02/2022
Delta Energy Group, Jiaozhou City, Qingdao, China	
Wetzel IB, Guben	
Wijbenga, PC Geldermalsen, The Netherlands	
Voith Paper, Heidenheim	
HS Zittau/Görlitz, Maschinenwesen	01/2022
Thermische Abfallbehandlung, Lauta	
Webb Institute, Glen Cove NY, USA	
TU Berlin, Umweltverfahrenstechnik	
SachsenEnergie, Dresden	
Doosan, Chang-won-si, Gyeongsangnam-do, South Korea	
KW3, LH Veenendaal, The Netherlands	
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Rudnick & Enners, Alpenrod	

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KW3, The Netherlands	
BASF Ludwigshafen	
Air-Consult, Jena	
Sjerp & Jongeneel, RB Zoetermeer, The Netherlands	11/2021
Maerz Ofenbau, Zürich, Switzerland	
RWE Supply & Trading, Essen	
Hahn IB, Dresden	10/2021
Therm, South Africa	
RWE Supply & Trading, Essen	
TH Nürnberg, Verfahrenstechnik	09/2021
RWE Supply & Trading, Essen	
Enseleit IB, Mansfeld	
SachsenEnergie, Dresden	
BSH Hausgeräte, Berlin	

Norsk Energi, Oslo, Norway	08/2021
AKM Industrieanlagen, Haltern	
Drill Cool Systems, Bakersfield CA, USA	
Siemens Energy Global, Erlangen	07/2021
Wulff & Umag, Husum	
Planungsbüro Waidhas, Chemnitz	
Burkhardt Energie Technik, Mühlhausen	
Lücke IB, Paderborn	06/2021
TU Dresden, Energieverfahrenstechnik	
Wärme, Hamburg	
AL-KO Therm, Kötz	
PCK Raffinerie, Schwedt	
Vogelsang & Benning, Bochum	05/2021
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VPC Group, Vetschau	
AVG, Köln	04/2021
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Jager Kältetechnik, Osnabrück	
T&M Automation, GR Leidschendam, The Netherlands	
RWE Supply & Trading, Essen	
Stadtwerke Leipzig	
Beuth Hochschule für Technik, Berlin	
Beleth IB, Woeth	02/2021
ZTL, Thal, Austria	
ETABO Bochum	
RWE Supply & Trading, Essen	
Onyx Germany, Berlin	
TU Dresden, Kältetechnik	
GOHL-KTK, Durmersheim	
Therm Development, South Africa	
thermofin, Heinsdorfergrund	
RWE Supply & Trading, Essen	01/2021
STEAG, Essen	
ETA Energieberatung, Pfaffenhofen	
Enex Power, Kirchseeon	

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Manders, The Netherlands	
RWE Supply & Tranding, Essen	
NEOWAT Lodz, Poland	
University of Duisburg-Essen, Duisburg	11/2020
Stellenbosch University, South Africa	

University De France-COMTe, France	
RWE, Essen	
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Isenmann Ingenierbüro	
University of Stuttgart, ITLR, Stuttgart	
Norsk Energi, Oslo, Norway	
TGM Kanis, Nürnberg	
Stadtwerke Neuburg	10/2020
Smurfit Kappa, Roermond, The Netherlands	
RWE, Essen	
Hochschule Zittau/Görlitz, Wirtschaftsingenieurwesen	
Stadtwerke, Neuburg	
ILK, Dresden	
ATESTEO, Alsdorf	
Hochschule Zittau/Görlitz, Maschinenwesen	
TH Nürnberg, Verfahrenstechnik	
Drill Cool, Bakersfield CA, USA	09/2020
RWE, Essen	
2Meyers Ingenieurbüro, Nürnberg	
FELUWA, Mürlenbach	
Stadtwerke Neuburg	
Caverion, Wien, Austria	
GMVA Niederrhein, Oberhausen	
INWAT Lodz, Poland	
Troche Ingenieurbüro, Hayingen	08/2020
CEA Saclay, France	
VPC, Vetschau	07/2020
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Exergie Etudes, Sarl, Switzerland	
AWG Wuppertal	
STEAG Energy Services, Zwingenberg	
Hochschule Braunschweig	06/2020
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TU Dresden, Energieverfahrenstechnik	
BASF SE, ESI/EE, Ludwigshafen	
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Ruchi Ingenieurbüro, Uster, Switzerland	
IWB, Basel, Switzerland	
Midiplan, Bietingen-Bissingen	05/2020
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RWE, Essen	
Leser, Hamburg	
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EWT Wassertechnik, Celle	
Hochschule Darmstadt	04/2020
MTU München CCP	
HAW Hamburg	03/2020

Hanon, Novi Jicin, Czech Republic	
TU Dresden, Kältetechnik	
MAN, Copenhagen, Denmark	
EnerTech, Radebeul	02/2020
LEAG, Cottbus	
B+B Enginering Magdeburg	
Hochschule Offenburg	
WIB, Dennheritz	01/2020
Universität Duisburg-Essen, Strömungsmaschinen	
Kältetechnik Dresen-Bremen	
TH Ingolstadt	
Vattenfall AB, Jokkmokk, Sweden	
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RWE, Essen	
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EEB ENERKO, Aldenhoven	
Robert Benoufa Energietechnik, Wiesloch	
Kehrein & Kubanek Klimatechnik, Moers	10/2019
Hanon Systems Autopal Services, Hluk, Czech Republic	
CEA Saclay, Gif Sur Yvette cedex, France	
Saudi Energy Efficiency Center SEEC, Riyadh, Saudi Arabia	
VPC, Vetschau	09/2019
jGanser PM + Engineering, Forchheim	
Endress+Hauser Flowtec AG, Reinach, Switzerland	
Ruchi IB, Uster, Switzerland	
ZWILAG Zwischenlager Würenlingen, Switzerland	08/2019
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Physikalisch Technische Bundesanstalt PTB, Braunschweig	
GMVA Oberhausen	07/2019
Endress+Hauser Flowtec AG, Reinach, Switzerland	
WARNICA, Waterloo, Canada	
MIBRAG, Zeitz	06/2019
Pöry, Zürich, Switzerland	
RWTH Aachen, Institut für Strahltriebe und Turbomaschinen	
Midiplan, Bietigheim-Bissingen	
GKS Schweinfurt	
HS Zittau/Görlitz, Wirtschaftswissenschaften und Wirtschaftsingenieurwesen	
ILK Dresden	
HZDR Helmholtz Zentrum Dresden-Rossendorf	
TH Köln, Technische Gebäudeausrüstung	05/2019
IB Knittel, Braunschweig	
Norsk Energi, Oslo, Norway	

STEAG, Essen	
Stora Enso, Eilenburg	
IB Lücke, Paderborn	
Haarslev, Sonderso, Denmark	
MAN Augsburg	
Wieland Werke, Ulm	04/2019
Fels-Werke, Elbingerode	
Univ. Luxembourg, Luxembourg	
BTU Cottbus, Power Engineering	03/2009
Eins-Energie Sachsen, Schwarzenberg	
TU Dresden, Kälte- und Kryotechnik	
ITER, St. Paul Lez Durance Cedex, France	
Fraunhofer UMSICHT, Oberhausen	
Comparex Leipzig for Spedition Thiele HEMMERSBACH	
Rückert NaturGas, Lauf/Pegnitz	
BASF, Basel, Switzerland	02/2019
Stadtwerke Leipzig	
Maerz Ofenbau Zürich, Switzerland	
Hanon Systems Germany, Kerpen	
Thermofin, Heinsdorfergrund	01/2019
BSH Berlin	

## 2018

Jaguar Energy, Guatemala	12/2018
WEBASTO, Gilching	
Smurfit Kappa, Oosterhout, Netherlands	
Univ. BW München	
RAIV, Liberec for VALEO, Prague, Czech Republic	11/2018
VPC Group Vetschau	
SEITZ, Wetzikon, Switzerland	
MVV, Mannheim	10/2018
IB Troche	
KANIS Turbinen, Nürnberg	
TH Ingolstadt, Institut für neue Energiesysteme	
IB Kristl & Seibt, Graz, Austria	09/2018
INEOS, Köln	
IB Lücke, Paderborn	
Südzucker, Ochsenfurt	08/2018
K&K Turbinenservice, Bielefeld	07/2018
OTH Regensburg, Elektrotechnik	
Comparex Leipzig for LEAG, Berlin	06/2018
Münstermann, Telgte	05/2018
TH Nürnberg, Verfahrenstechnik	
Universität Madrid, Madrid, Spanien	
HS Zittau/Görlitz, Wirtschaftsingenieurwesen	
HS Niederrhein, Krefeld	
Wilhelm-Büchner HS, Pfungstadt	03/2018

GRS, Köln	
WIB, Dennheritz	
RONAL AG, Härklingen, Schweiz	02/2018
Ingenieurbüro Leipert, Riegelsberg	
AIXPROCESS, Aachen	
KRONES, Neutraubling	
Doosan Lentjes, Ratingen	01/2018