CAHD
Computer-aided hopper design

A short introduction

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Dr. Dietmar Schulze
Powder testers & software

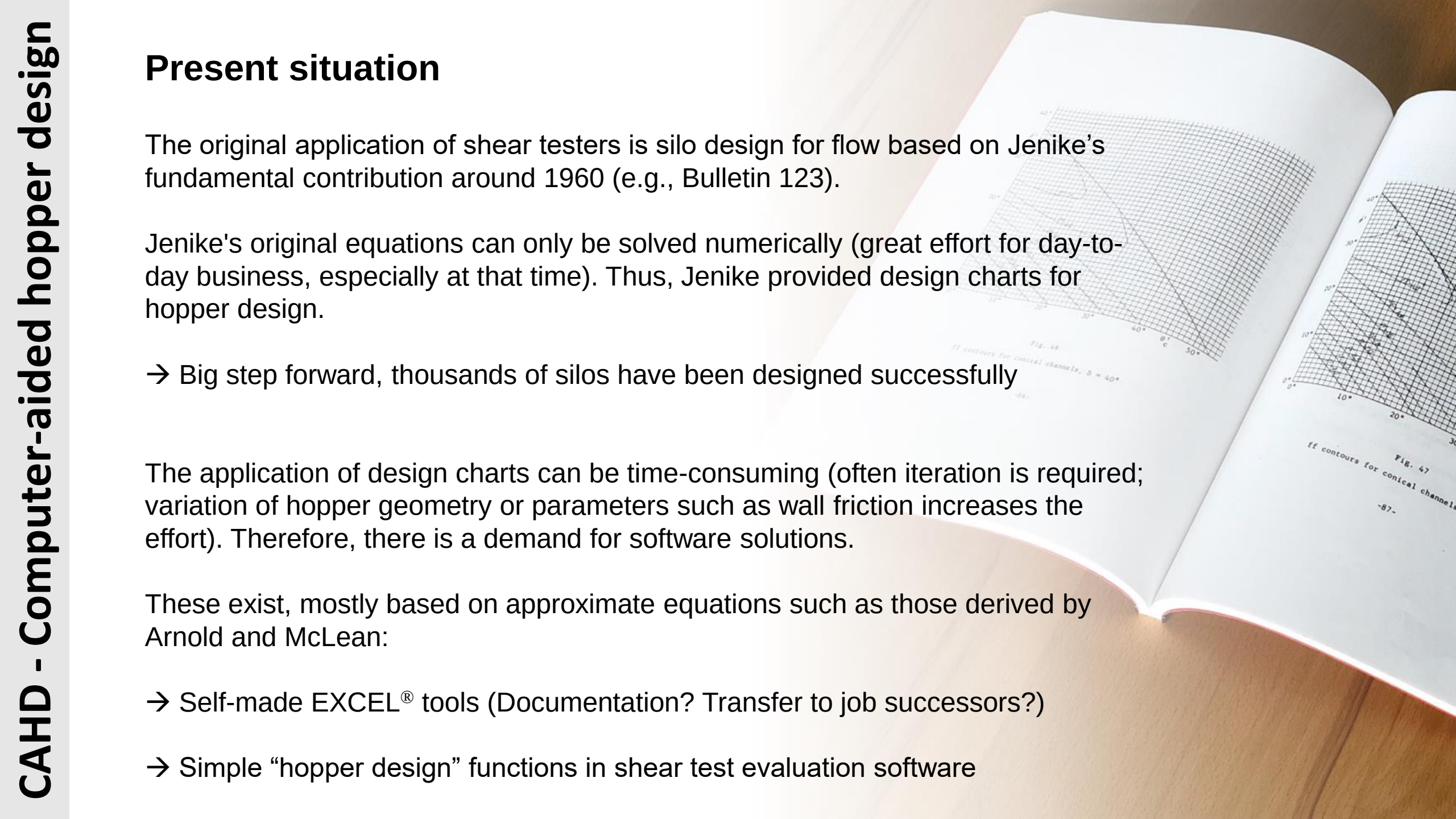
Motivation

Present situation

The original application of shear testers is silo design for flow based on Jenike's fundamental contribution around 1960 (e.g., Bulletin 123).

Jenike's original equations can only be solved numerically (great effort for day-to-day business, especially at that time). Thus, Jenike provided design charts for hopper design.

→ Big step forward, thousands of silos have been designed successfully



The application of design charts can be time-consuming (often iteration is required; variation of hopper geometry or parameters such as wall friction increases the effort). Therefore, there is a demand for software solutions.

These exist, mostly based on approximate equations such as those derived by Arnold and McLean:

→ Self-made EXCEL® tools (Documentation? Transfer to job successors?)

→ Simple "hopper design" functions in shear test evaluation software

CAHD - Computer-aided hopper design

Goal: Interactive program that overcomes the above restrictions

→ Based on Jenike's original equations which are solved numerically; optional application of other approaches/modifications

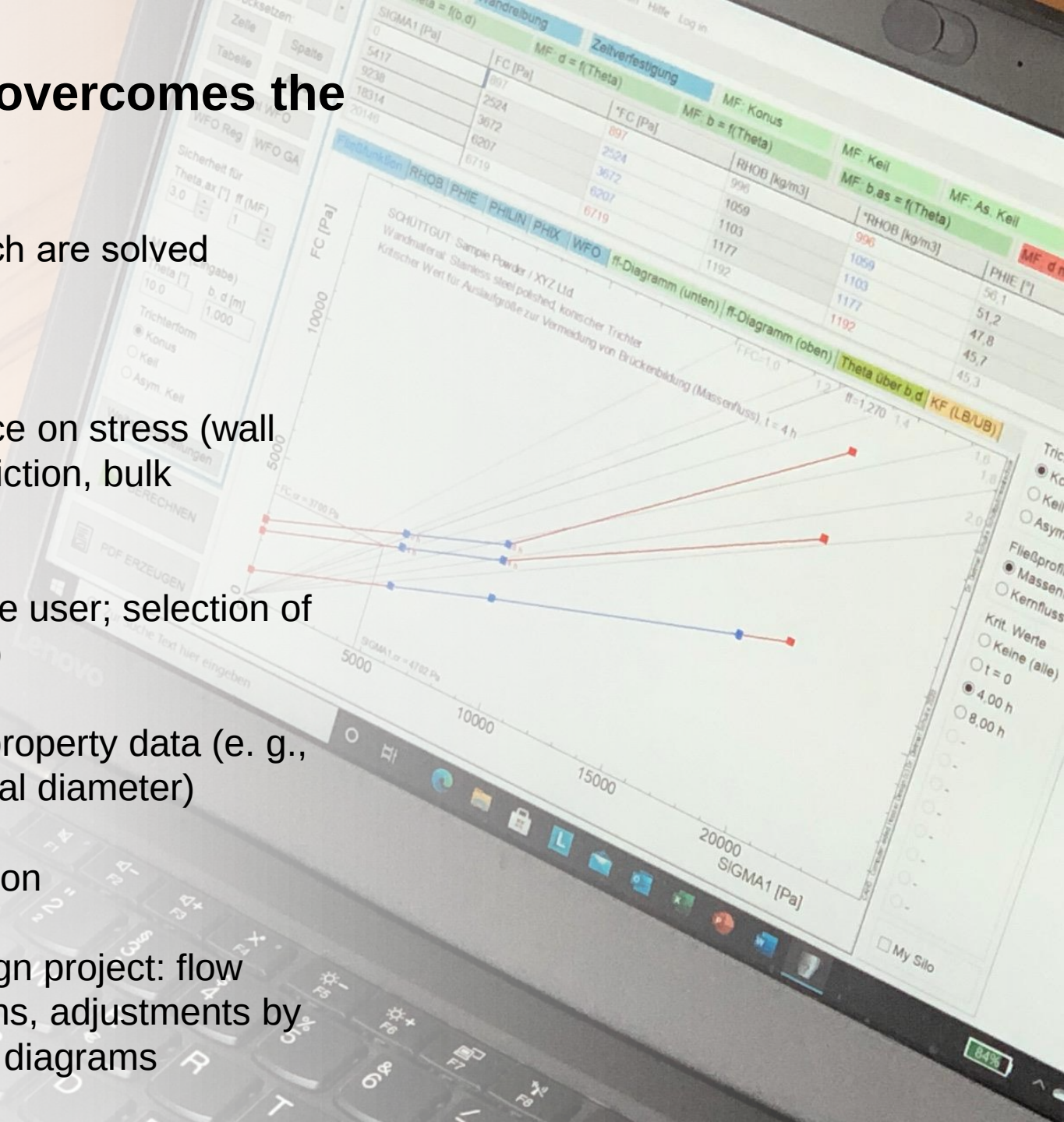
→ Consideration of flow property dependence on stress (wall friction angle, effective angle of internal friction, bulk density…)

→ Interactive (e. g., curve fit controlled by the user; selection of "mean" or "maximum" wall friction angles)

→ Solutions for the complete range of flow property data (e. g., hopper slope angles for mass flow vs. local diameter)

→ Transparent and comprehensible evaluation

→ Documentation (pdf) of each hopper design project: flow properties, applied theories, safety margins, adjustments by the user, and design results in tables and diagrams



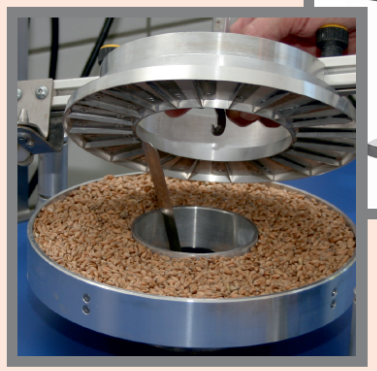
The program

CAHD - Computer-aided hopper design

Workflow: Measurement → evaluation → hopper design → silo

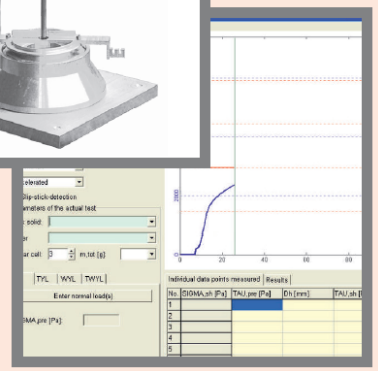
Start

1 Measure the bulk solid's flow properties (Ring Shear Tester and control software RST-CONTROL 95)



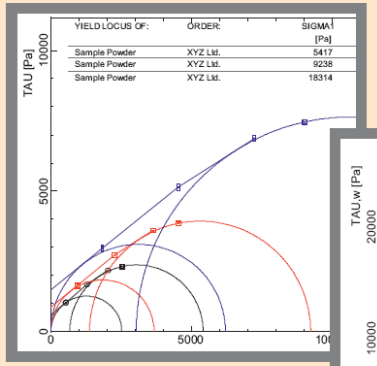
Shear cell of Ring Shear Tester RST-01.pc

Time consolidation test

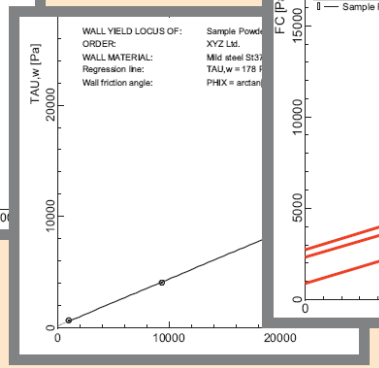


RST-CONTROL 95

Yield loci

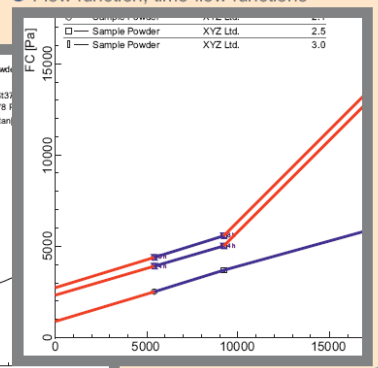


2 Test results: Strength, bulk density, internal friction, wall friction, and time consolidation

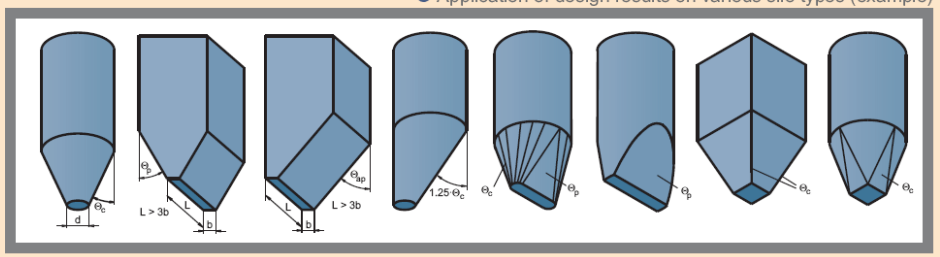


Wall yield locus

Flow function, time flow functions

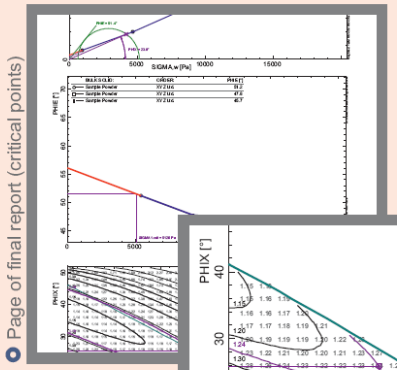


Application of design results on various silo types (example)

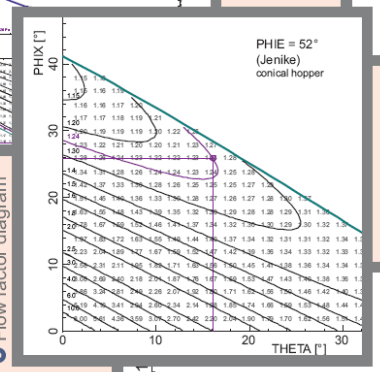


4 Finally apply results to get the optimal silo.

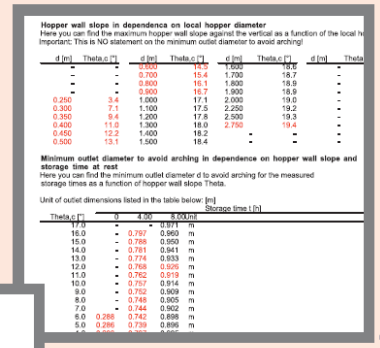
Page of final report (critical points)



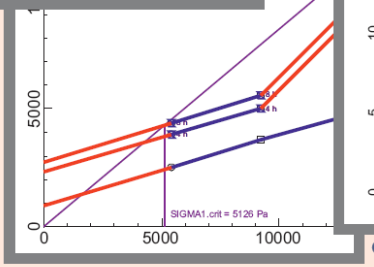
Flow factor diagram



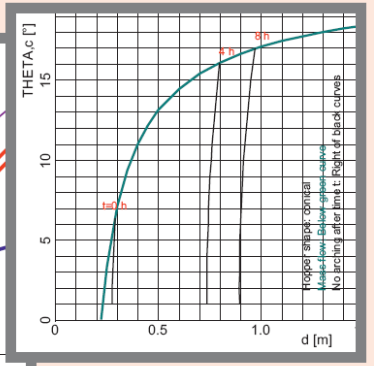
Page of final report (slope vs. diameter)



3 Computer-aided hopper design: Program generates ff-diagrams, iteractively determines outlet dimensions and hopper angles, and creates a final report.



Determination of critical outlet diameter



Maximum hopper slope vs. diameter

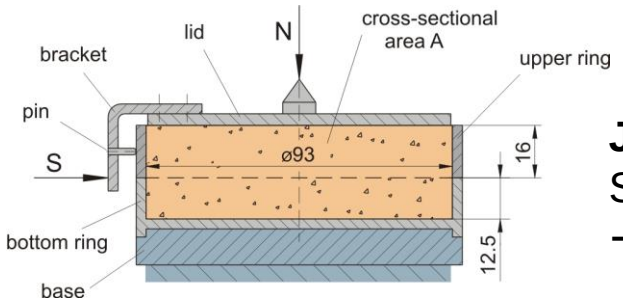
Data import (Schulze ring shear testers, Jenike shear tester)

Ring Shear Tester RST-01.01
Software: RSV 95
→ EIF files (EIF: extended input file)

Ring Shear Tester RST-01.pc
Software: RST-CONTROL 95
→ EIF files (EIF: extended input file)
→ FPE files (FPE: flow properties exchange file)

Ring Shear Tester RST-XS
Software: RST-CONTROL 95
→ EIF files (EIF: extended input file)
→ FPE files (FPE: flow properties exchange file)

Ring Shear Tester RST-XS
Software: RST-CONTROL 95
→ EIF files (EIF: extended input file)
→ FPE files (FPE: flow properties exchange file)

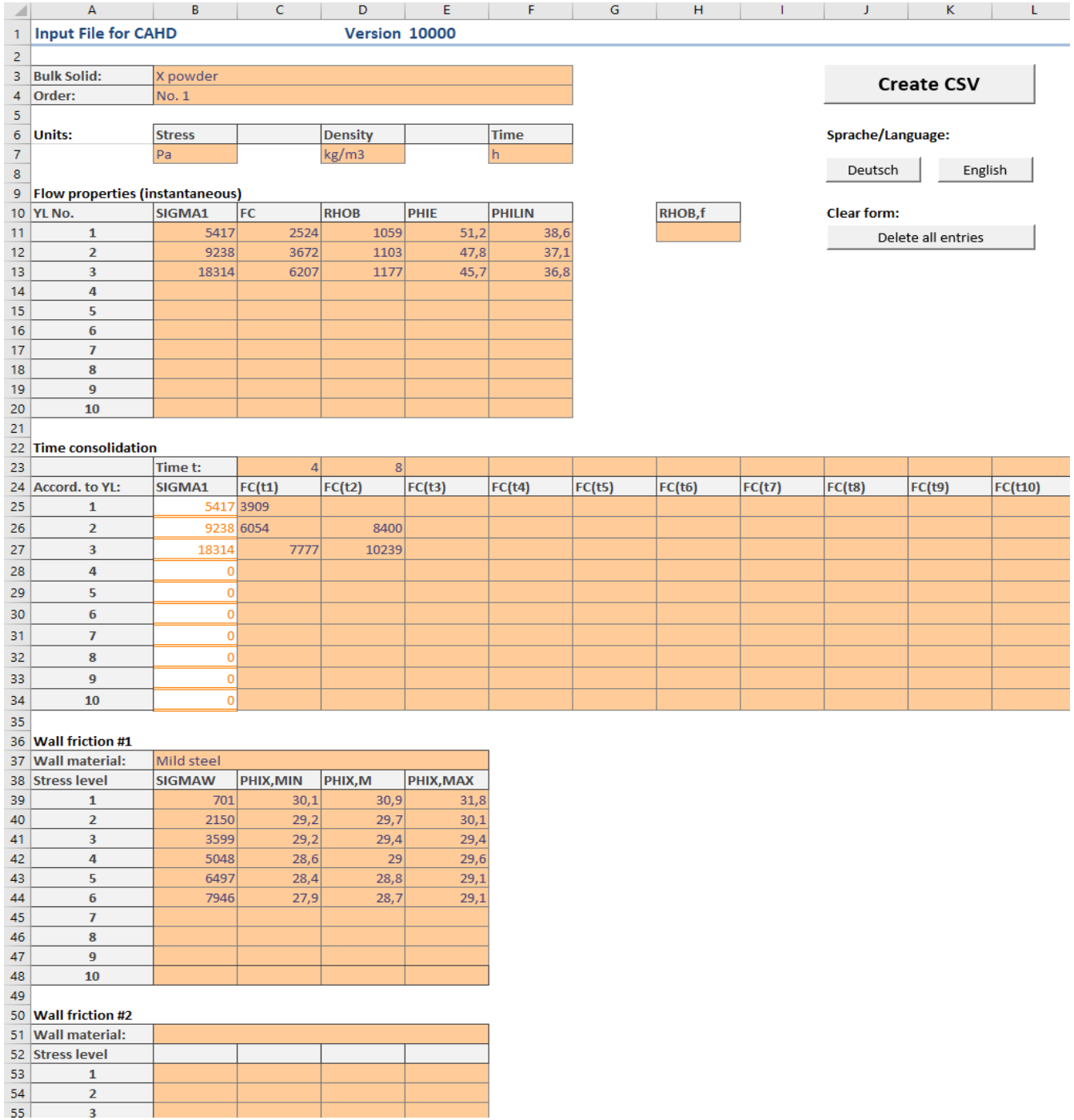


Jenike-type Shear Tester
Software: SV 95
→ FPE files (FPE: flow properties exchange file)

Import of flow properties from other sources

Template for Microsoft EXCEL®
→ CSV file

Caution! Data must have been obtained with reliable testers.



Input File for CAHD — Version 10000

Bulk Solid: X powder
Order: No. 1

Create CSV

Sprache/Language: Deutsch | English

Clear form: Delete all entries

Units: Stress [Pa] | Density [kg/m3] | Time [h]

Flow properties (instantaneous)

YL No.	SIGMA1	FC	RHOB	PHIE	PHILIN
1	5417	2524	1059	51,2	38,6
2	9238	3672	1103	47,8	37,1
3	18314	6207	1177	45,7	36,8
4					
5					
6					
7					
8					
9					
10					

RHOB,f

Time consolidation

	Time t:	4	8								
Accord. to YL:	SIGMA1	FC(t1)	FC(t2)	FC(t3)	FC(t4)	FC(t5)	FC(t6)	FC(t7)	FC(t8)	FC(t9)	FC(t10)
1	5417	3909									
2	9238	6054	8400								
3	18314	7777	10239								
4	0										
5	0										
6	0										
7	0										
8	0										
9	0										
10	0										

Wall friction #1

Wall material: Mild steel

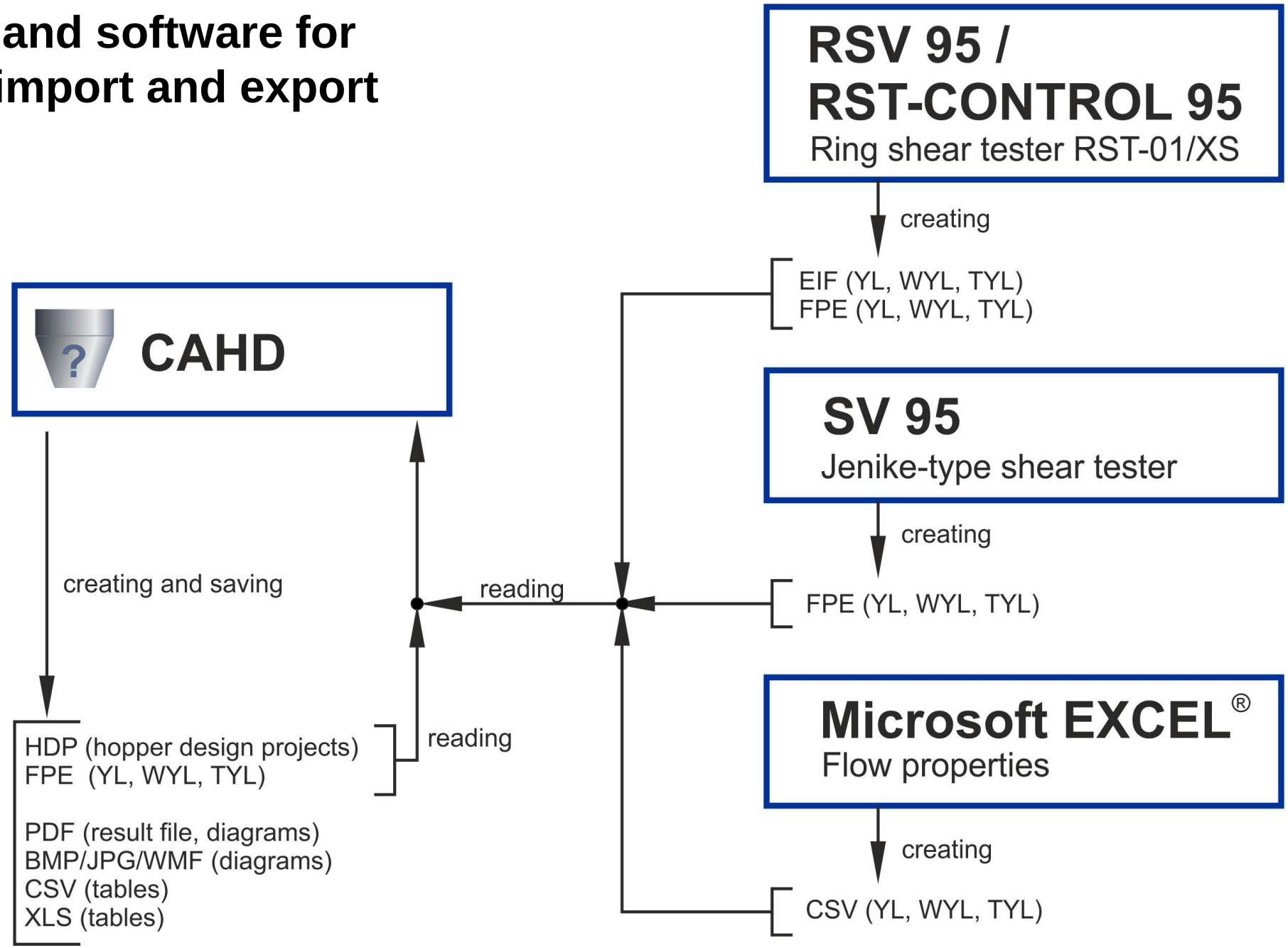
Stress level	SIGMAW	PHIX,MIN	PHIX,M	PHIX,MAX
1	701	30,1	30,9	31,8
2	2150	29,2	29,7	30,1
3	3599	29,2	29,4	29,4
4	5048	28,6	29	29,6
5	6497	28,4	28,8	29,1
6	7946	27,9	28,7	29,1
7				
8				
9				
10				

Wall friction #2

Wall material:

Stress level				
1				
2				
3				

Files and software for data import and export



Applied theories and options

A. W. Jenike (Bull. 123) 1964/1980
→ Mass flow: Arching
→ Funnel flow: Ratholing (lower/upper bound), Arching

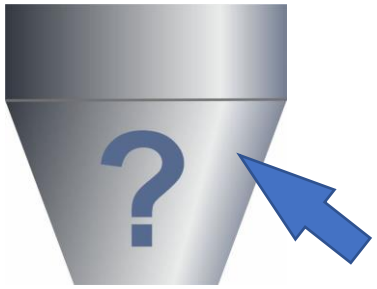
ff-values and mass flow boundaries have been calculated for φ_e
varied in in steps of 1°
Option: extended range φ_e = 20° to φ_e = 80°.

Option
P. C. Arnold / A. G. McLean:
Analytical flow factors ff (based on G. Enstad's approach)

Option
O. Molerus:
Smaller ff-values for steep hoppers / low wall friction

Option
A. W. Roberts:
Ratholing: Modification of Jenike's upper bound approach (considering anisotropic behaviour)

Working with the program



CAHD v1.0

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Yield loci (diagram)

☐ 1 ☐ 5 ☐ 9
☐ 2 ☐ 6 ☐ 10
☐ 3 ☐ 7 All
☐ 4 ☐ 8 No

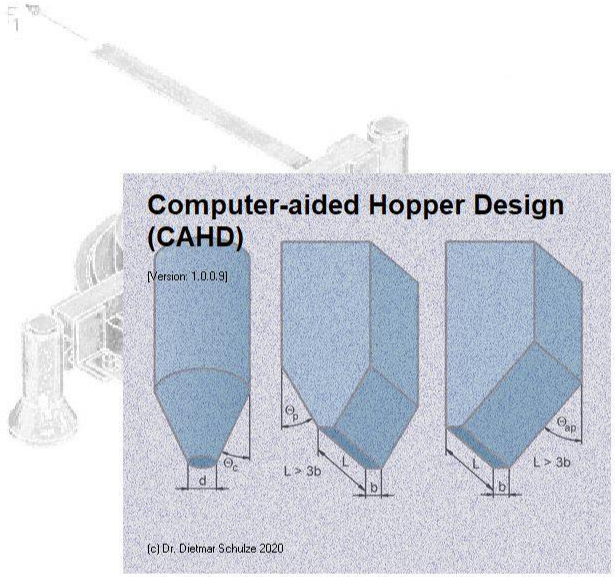
Diagram type

Yield locus/loci

Options

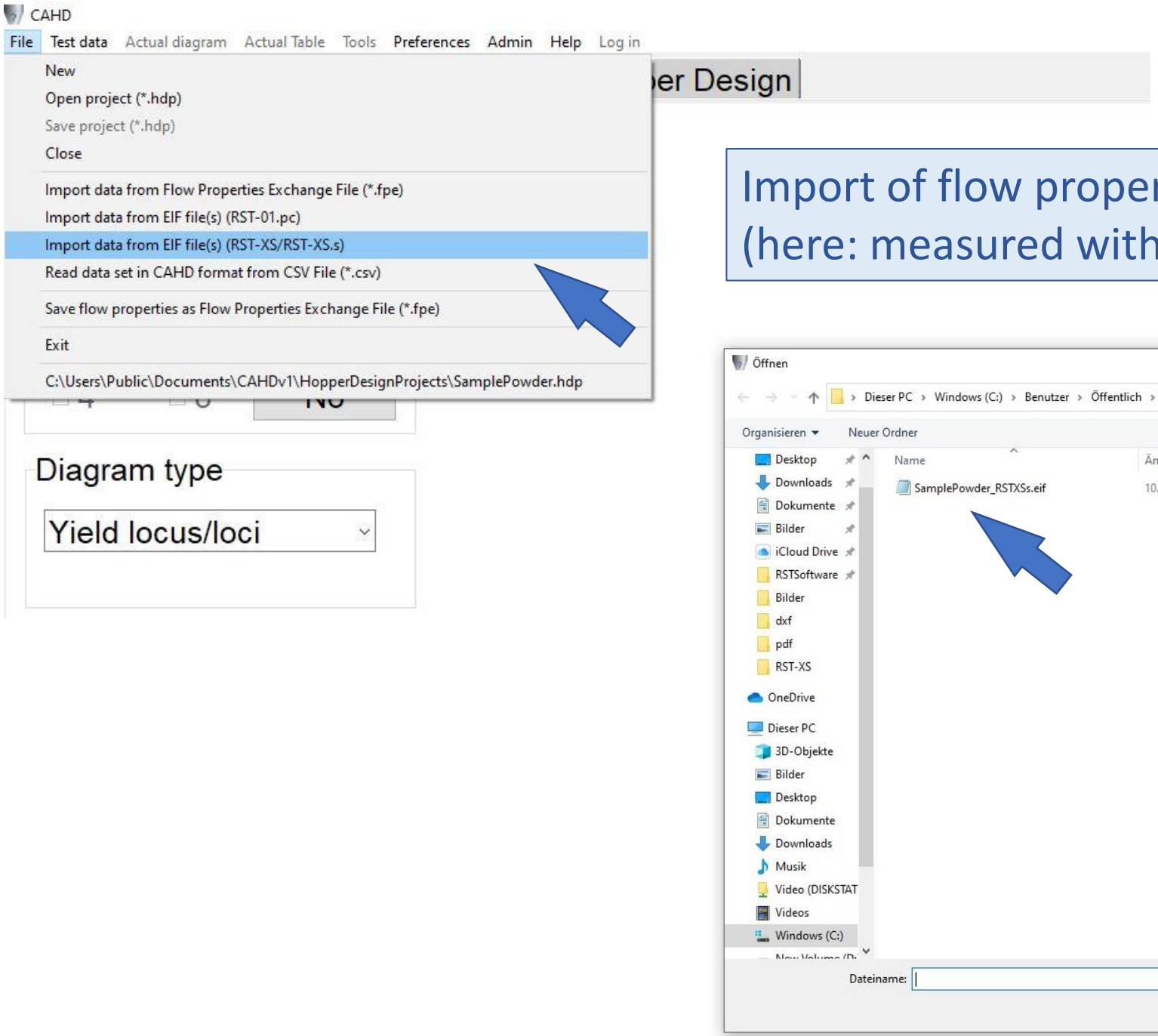
Full screen
☑ Legend
☑ SIGMA1 Mohr circle
☑ FC Mohr circle
☐ PHIE line
☑ Data points
☑ Lines ☐ Regr.
☐ ☐ Grid
☐ FFC = 1; 2; 4; 10
☐ FFC = 1; 1.2 .. 2.0
☐ FFC = 0

CAHD splash screen

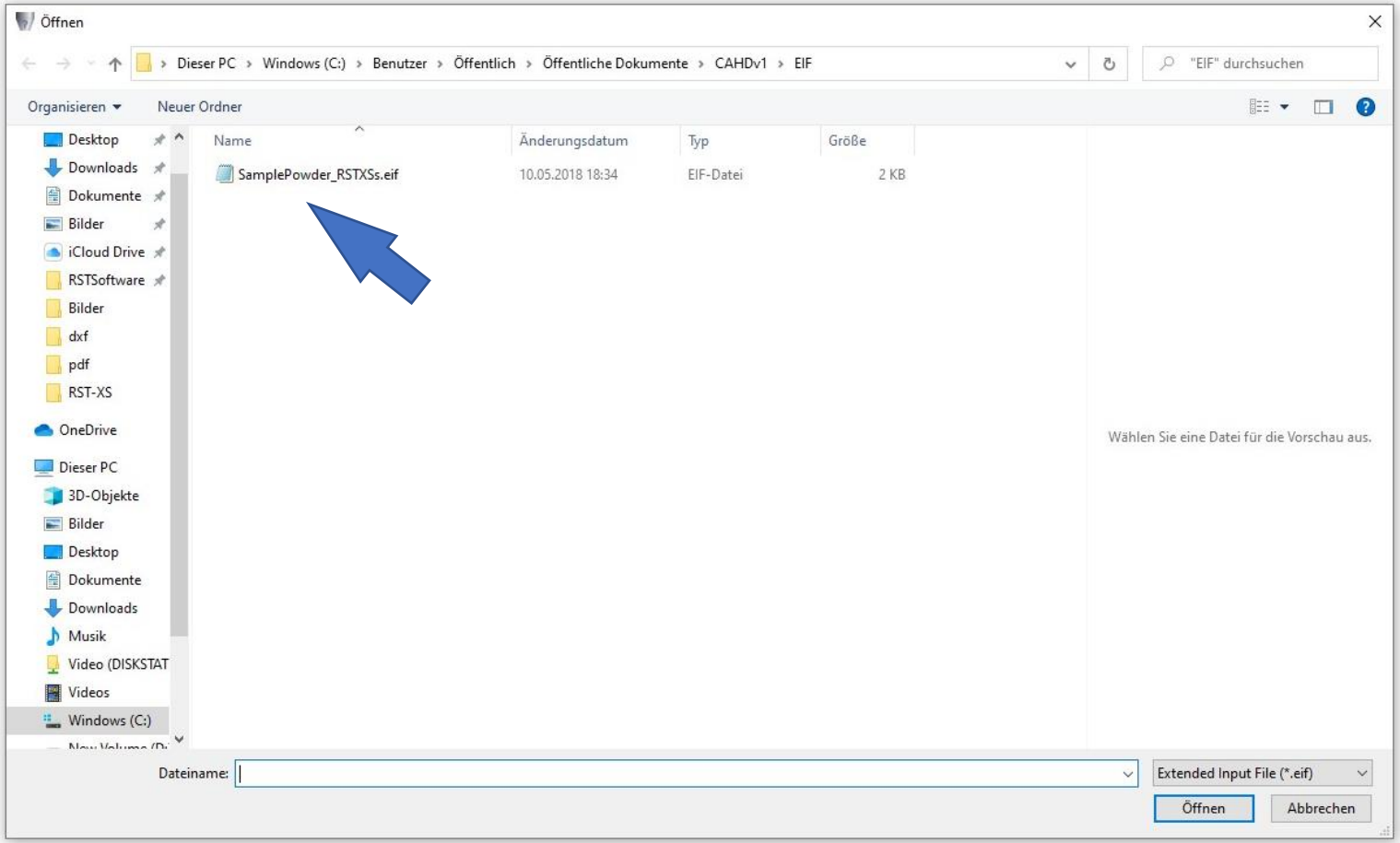


No.	SIGMA1 [kPa	FC [kPa]	FFC	FFRHO	TAU,C [kPa	RHOB [kg/m3	PHIE [°]	PHILIN [°	PHISF [°]	Bulk Solid	Order
1											
2											
3											
4											
5											
6											

Zur Suche Text hier eingeben



Import of flow properties from EIF file
(here: measured with Ring Shear Tester RST-XS.s



CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Yield loci (diagram)

1 5 9
2 6 10
3 7 All
4 8 No

Diagram type

Yield locus/loci

Options

Full screen
Legend
SIGMA1 Mohr circle
FC Mohr circle
PHIE line
Data points
Lines Regr.
Grid
FFC = 1; 2; 4; 10
FFC = 1; 1.2 .. 2.0
FFC = 0

CAHD shows contents of EIF file.
Flow properties to be imported are selected.

Choice of data to append

Yield loci:
- Sample Powder ; XYZ Ltd. ; N,pre = 1.05697 kg
- Sample Powder ; XYZ Ltd. ; N,pre = 1.90234 kg
- Sample Powder ; XYZ Ltd. ; N,pre = 3.80467 kg

Time yield loci corresponding to yield locus::
- Time yield loci corresp. to yield locus no. 1
- Time yield loci corresp. to yield locus no. 2

Wall yield loci:
- Sample Powder ; XYZ Ltd. ; Mild steel St37

Uncheck all
Check all
CANCEL
OK

No.	SIGMA1 [kPa	FC [kPa]	FFC	FFRHO	TAU,C [kPa	RHOB [kg/m3	PHIE [°]	PHILIN [°	PHISF [°]	Bulk Solid	Order
1											
2											
3											
4											
5											
6											

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Yield loci (diagram)

1 2 3 4 5 6 7 8 9 10

All No

Diagram type

Yield locus/loci

Options

Full screen

Legend

SIGMA1 Mohr circle

FC Mohr circle

PHIE line

Data points

Lines Regr.

Grid

FFC = 1; 2; 4; 10

FFC = 1; 1.2 .. 2.0

FFC = 0

YIELD LOCUS OF:	ORDER:	SIGMA1 [kPa]	FC [kPa]	FFC [-]	RHOB [kg/m3]	PHIE [°]	PHILIN [°]	PHISF [°]
Sample Powder	XYZ Ltd.	5.417	2.523	2.1	1066	51	39	42
Sample Powder	XYZ Ltd.	9.239	3.671	2.5	1114	48	37	40
Sample Powder	XYZ Ltd.	18.315	6.205	3.0	1195	46	37	40

TAU [kPa]

SIGMA [kPa]

0 5 10 15

Three yield loci and associated flow properties

CAHD - Computer-aided Hopper Design (c) Dr. Dietmar Schulze Schüttgutmesstechnik

No.	SIGMA1 [kPa]	FC [kPa]	FFC	FFRHO	TAU,C [kPa]	RHOB [kg/m3]	PHIE [°]	PHILIN [°]	PHISF [°]	Bulk Solid	Order
1	5.417	2.523	2.15	2.29	0.581	1066	51.2	38.6	42.5	Sample Powder	XYZ Ltd.
2	9.239	3.671	2.52	2.80	0.874	1114	47.8	37.1	40.4	Sample Powder	XYZ Ltd.
3	18.315	6.205	2.95	3.53	1.485	1195	45.7	36.8	39.5	Sample Powder	XYZ Ltd.
4											
5											
6											

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Wall yield locus no.

1 5 9
2 6 10
3 7 All
4 8 No

Diagram type

- Wall yield locus
- PHIX = f(SIGMA,w)

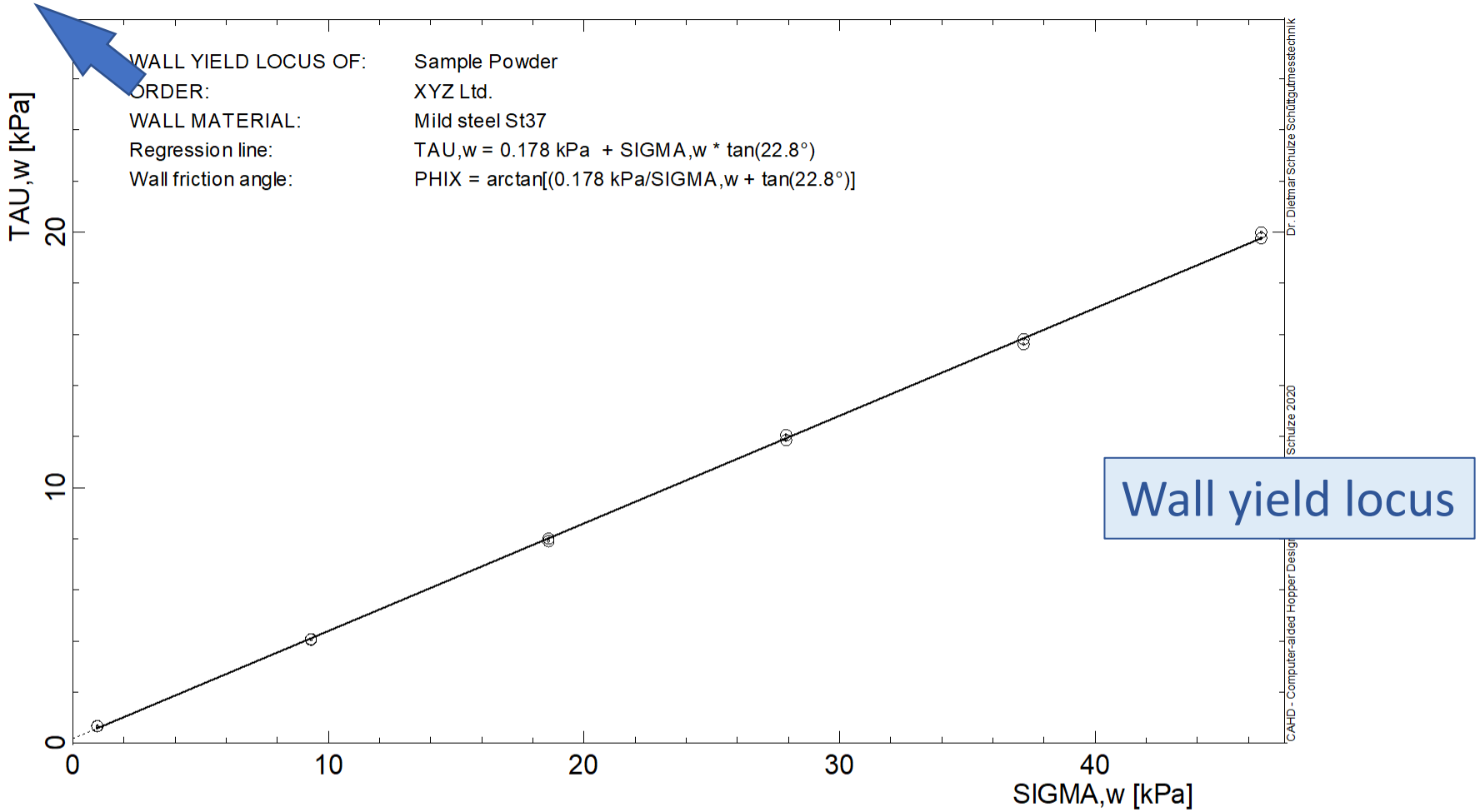
Options

Full screen

- Legend
- Data points
- Lines
- Grid
- Min. values
- Max. values
- Range x-axis

0 [kPa]

- Black and white



Wall yield locus no. 1:

SIGMA,w [kPa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	SIGMA,w [kPa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]
0.955	34.7	34.9	35.1				
9.320	23.5	23.6	23.6				
18.613	23.0	23.1	23.3				
27.907	23.0	23.2	23.4				
37.200	22.8	22.9	23.0				
46.494	23.0	23.2	23.3				

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

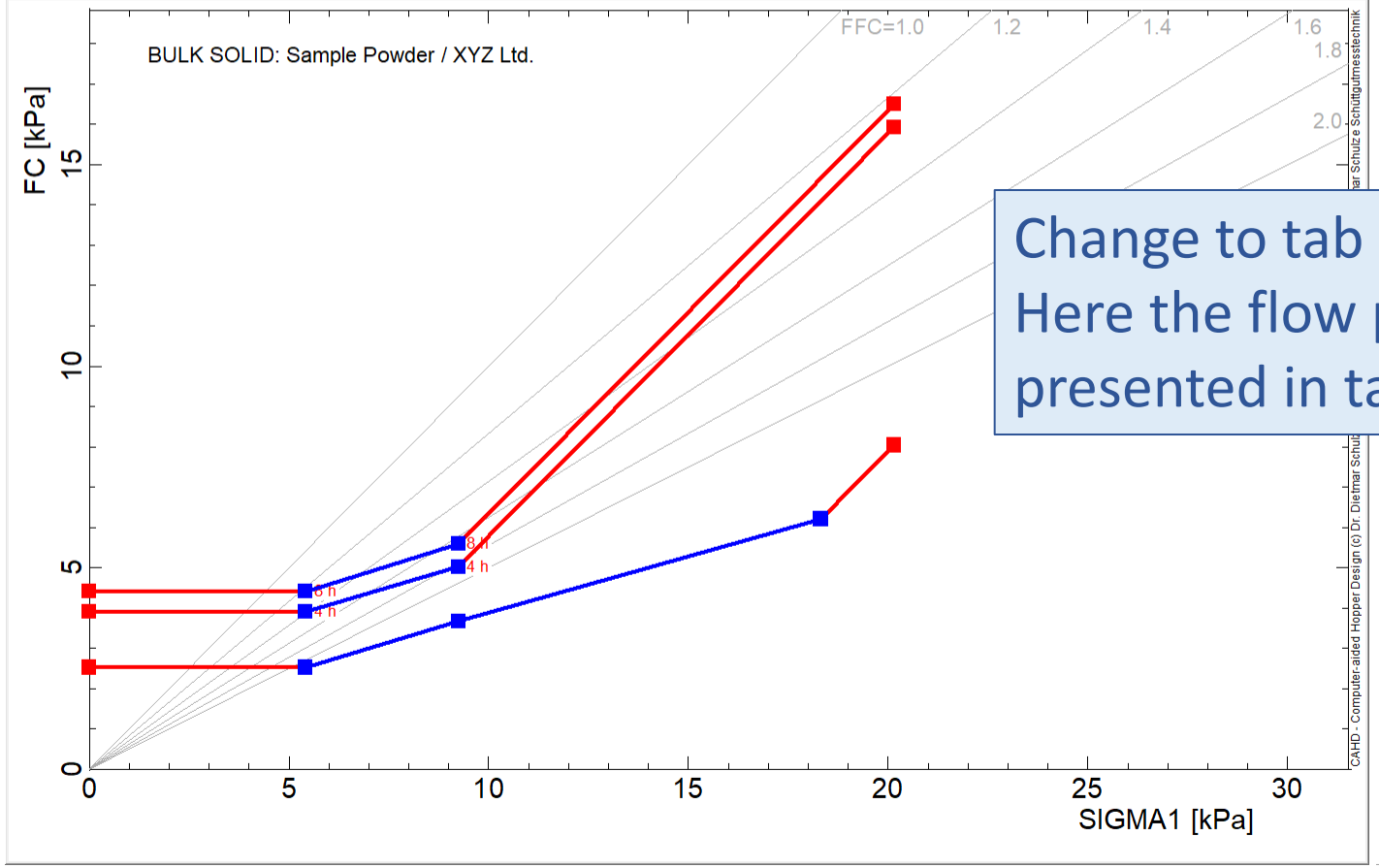
CREATE PDF

Yield loci | Wall fric | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	999	999	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow

My Silo

Change to tab “Hopper Design”: Here the flow properties are presented in tables and diagrams.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape

- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

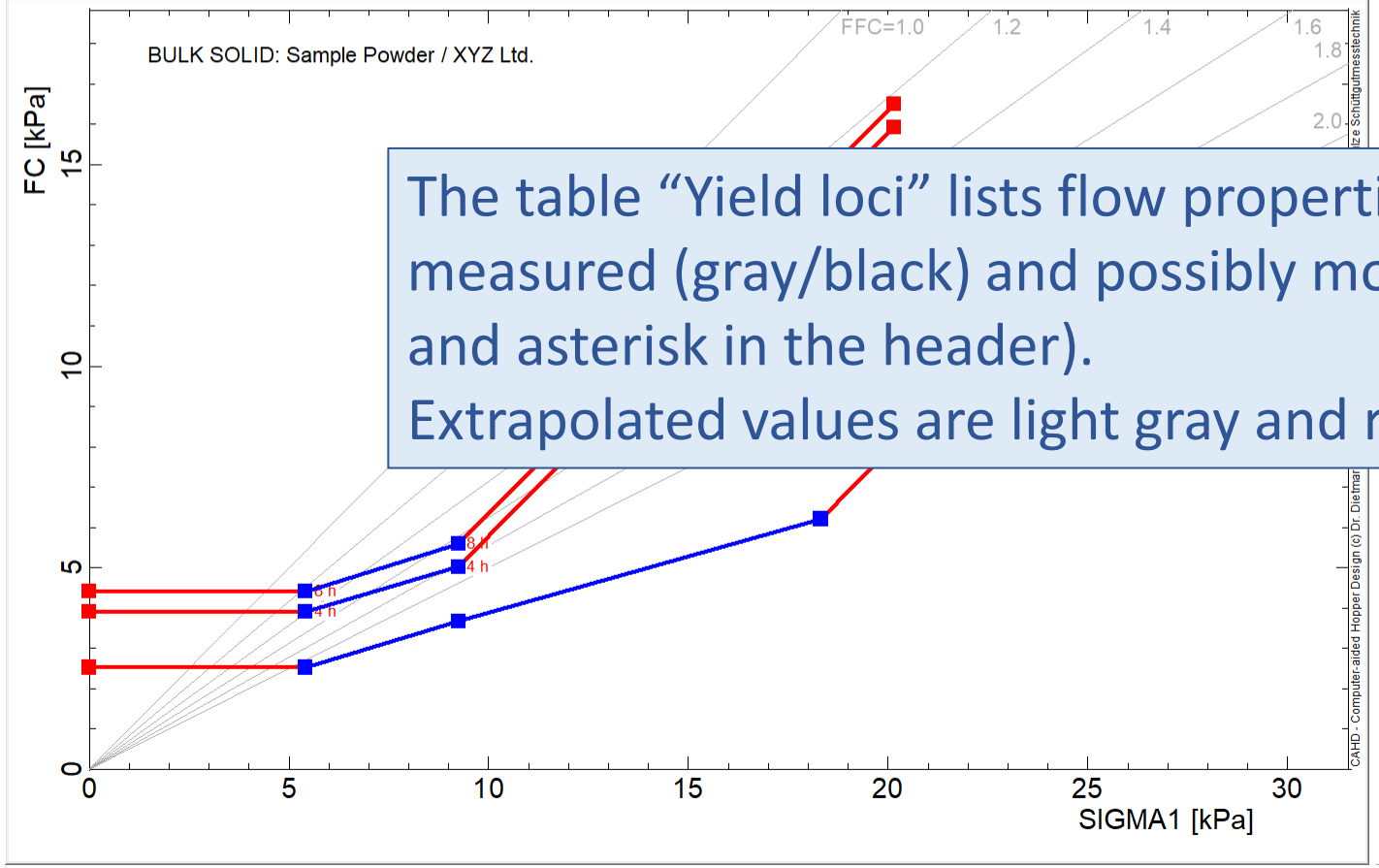
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	999	999	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape

- Cone
- Wedge
- Asym. wedge

Flow profile

My Silo

The table “Yield loci” lists flow properties in two columns each: measured (gray/black) and possibly modified (red/blue and asterisk in the header).
Extrapolated values are light gray and red, respectively.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column

Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3

ff (MF) 1

My Silo (data input)

Theta [°]

b, d [m]

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

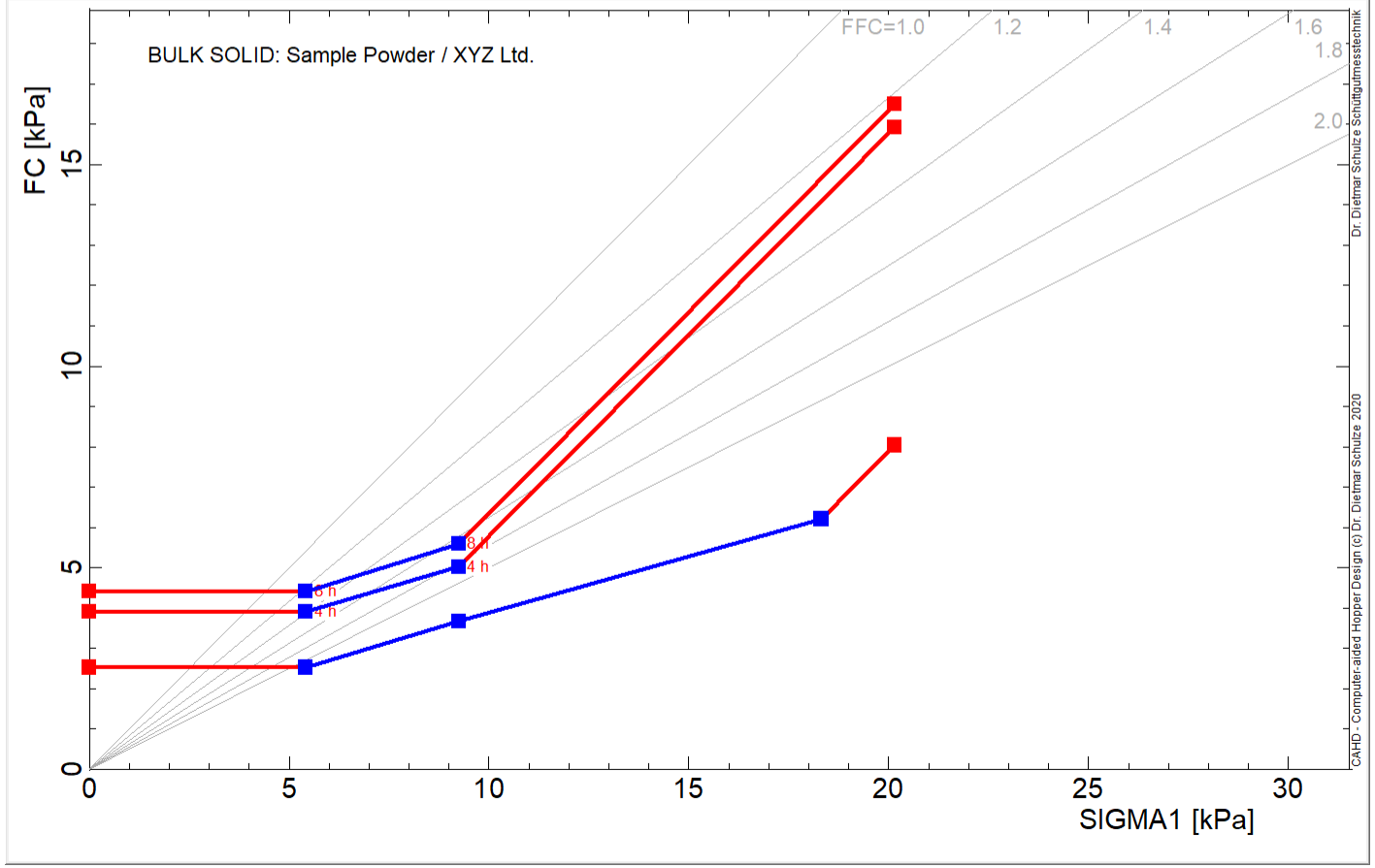
Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa] | t [h]	4.00	*4.00	8.00	*8.00
0.000	3.907	3.907	4.404	4.404
5.417	3.907	3.907	4.404	4.404
9.239	5.025	5.025	5.587	5.587
18.315				
20.147	15.932	15.932	16.495	16.495

Table with results of time consolidation tests.

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile

- (•) Mass flow
- ( ) Funnel flow

Crit. values

- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] | b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

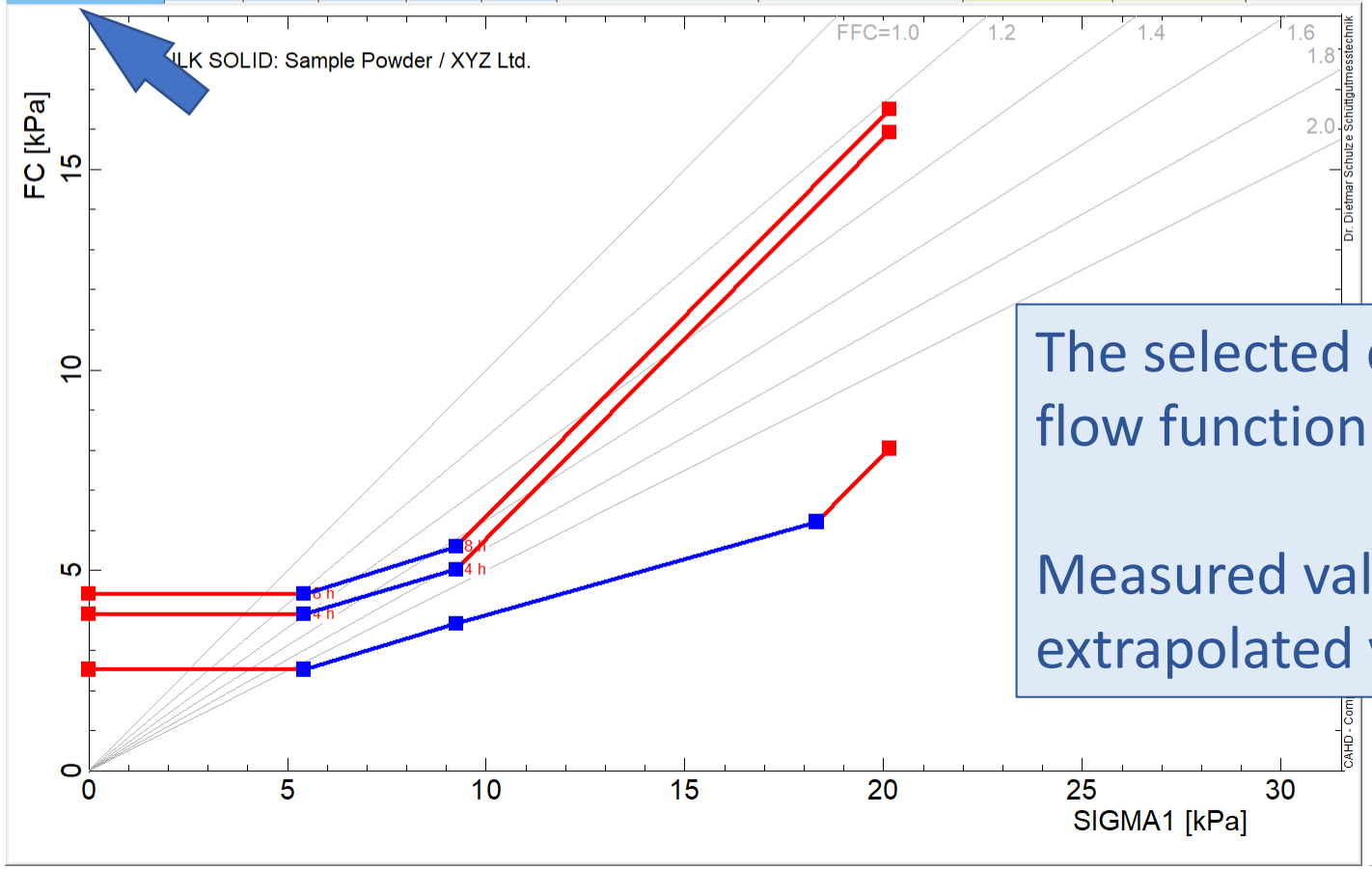
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	999	999	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values

My Silo

The selected diagram shows the flow function and time flow functions.

Measured values are blue, extrapolated values are red.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

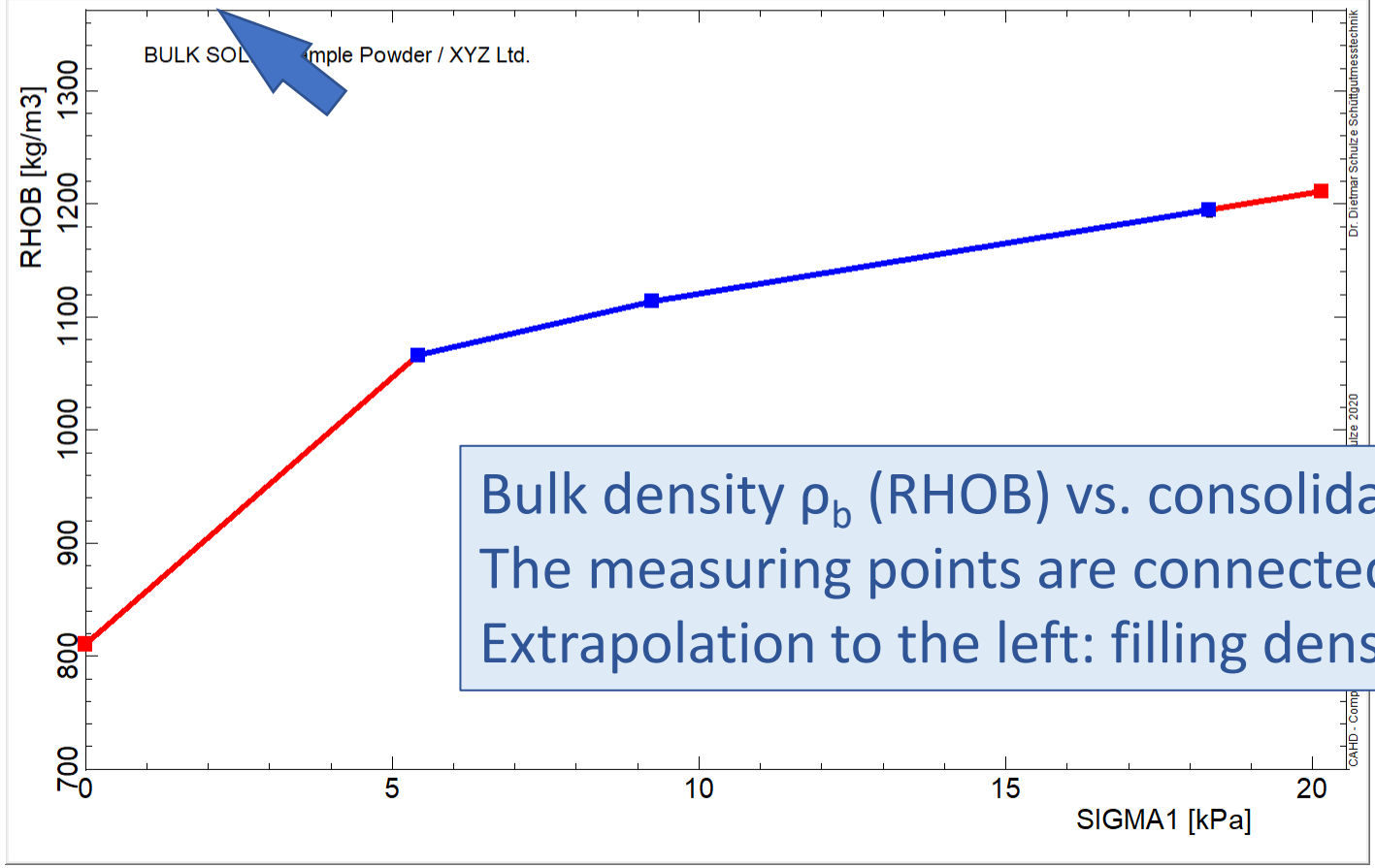
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h
- 8.00 h
- -
- -

My Silo

Bulk density ρ_b (RHOB) vs. consolidation stress σ_1 (SIGMA1)
The measuring points are connected with lines.
Extrapolation to the left: filling density, $\rho_{b,f}$ (optional)

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

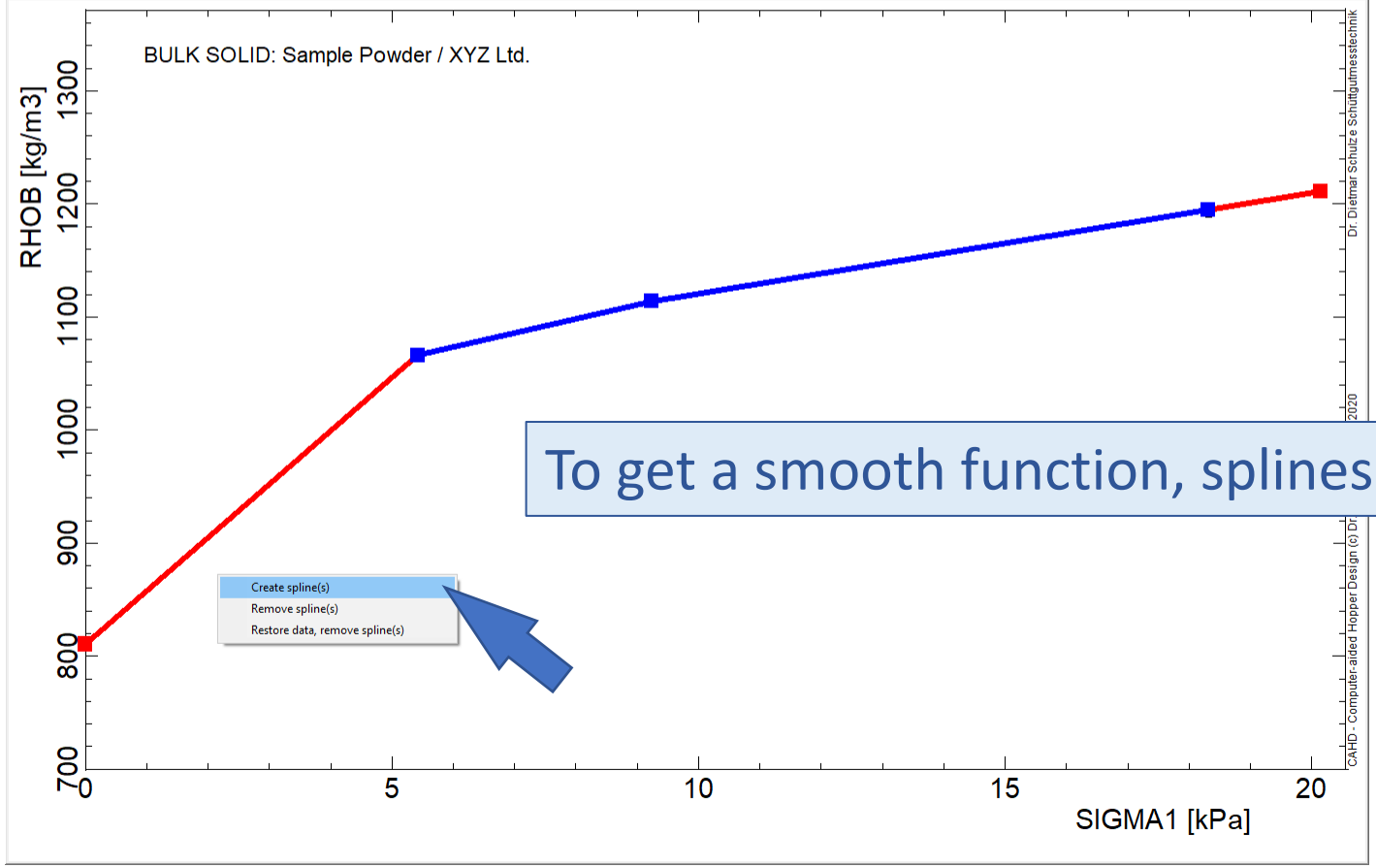
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



To get a smooth function, splines can be created.

Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h

My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

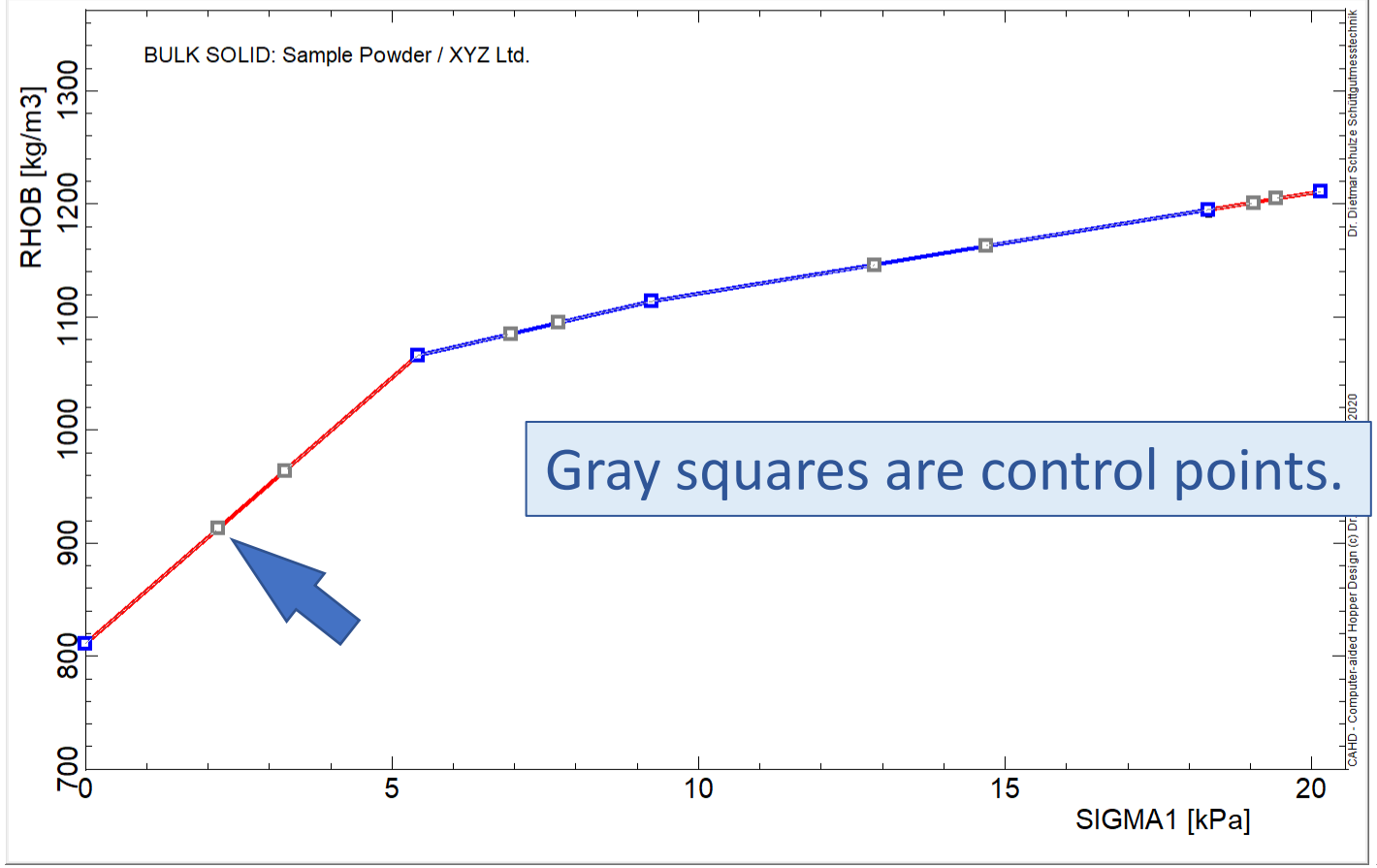
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

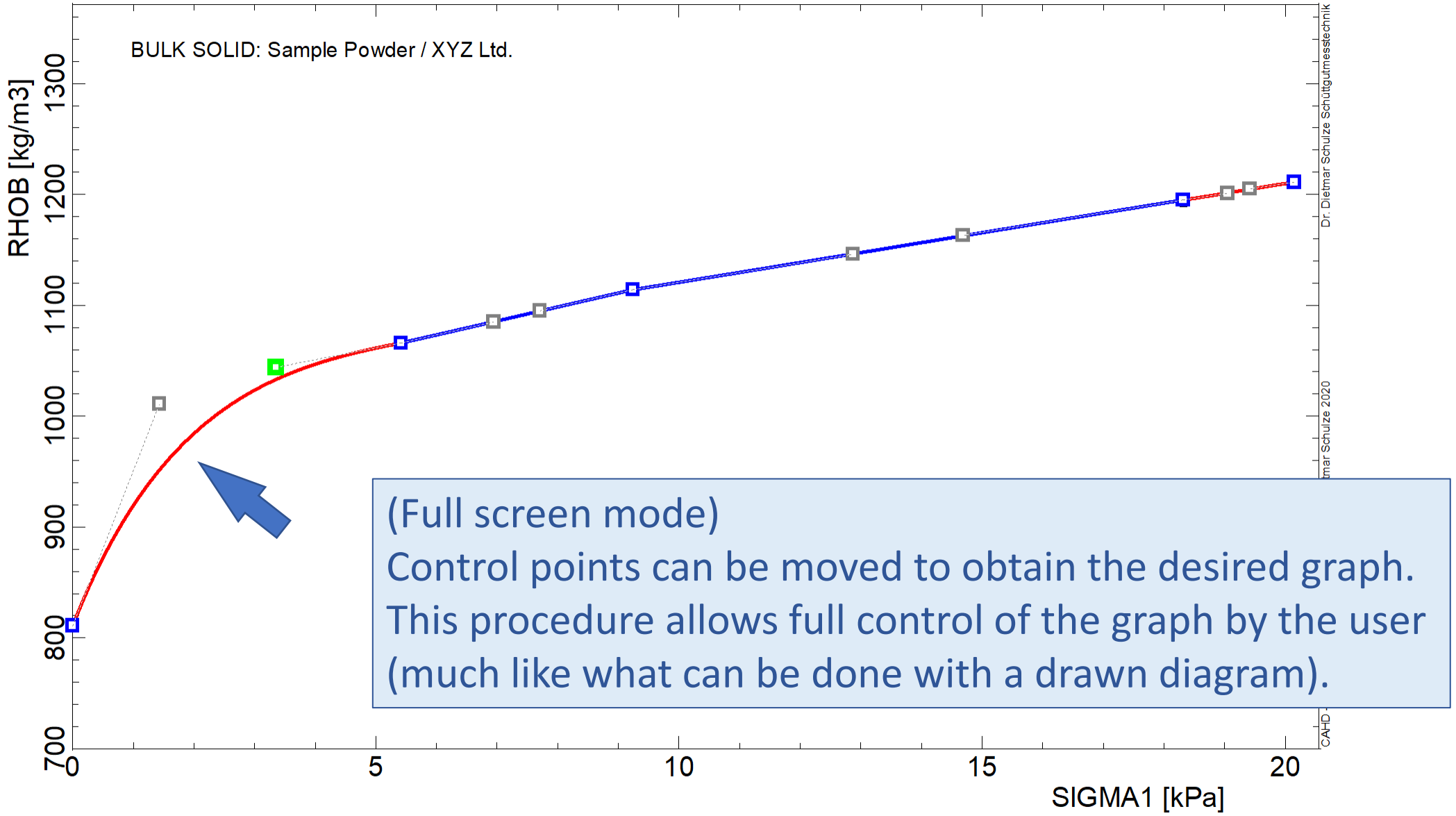
Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

[ ] My Silo

Zur Suche Text hier eingeben

SIGMA1 [kPa]: 2.873 RHOB [kg/m3]: 1047.25 Error approx. RHOB [kg/m3]: 0.63 Error approx. SIGMA1 [kPa]: 11.4482 Screen coordinates: [358;642]



(Full screen mode)
Control points can be moved to obtain the desired graph.
This procedure allows full control of the graph by the user (much like what can be done with a drawn diagram).

Close

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

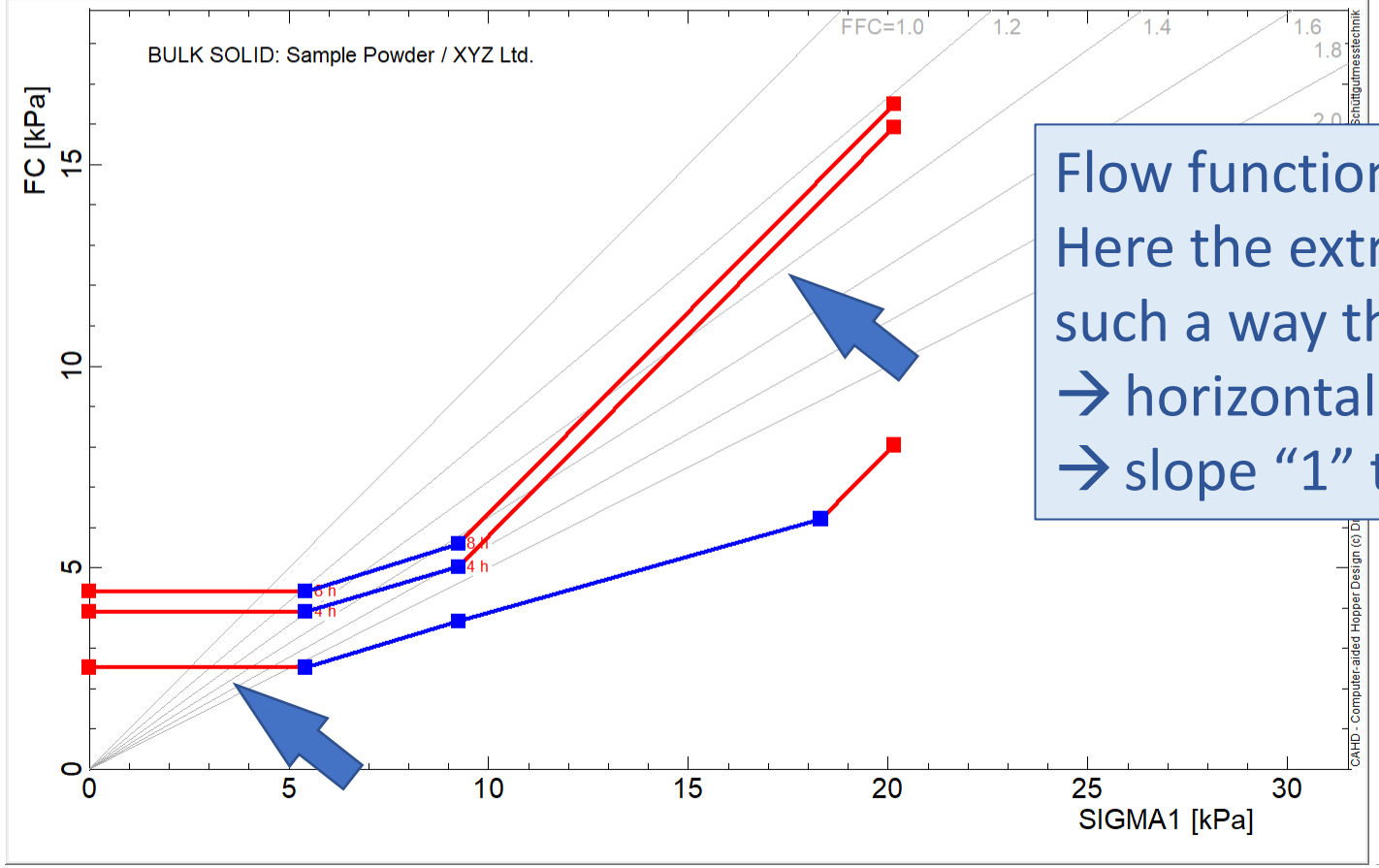
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	2.523	999	999	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	8.037	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



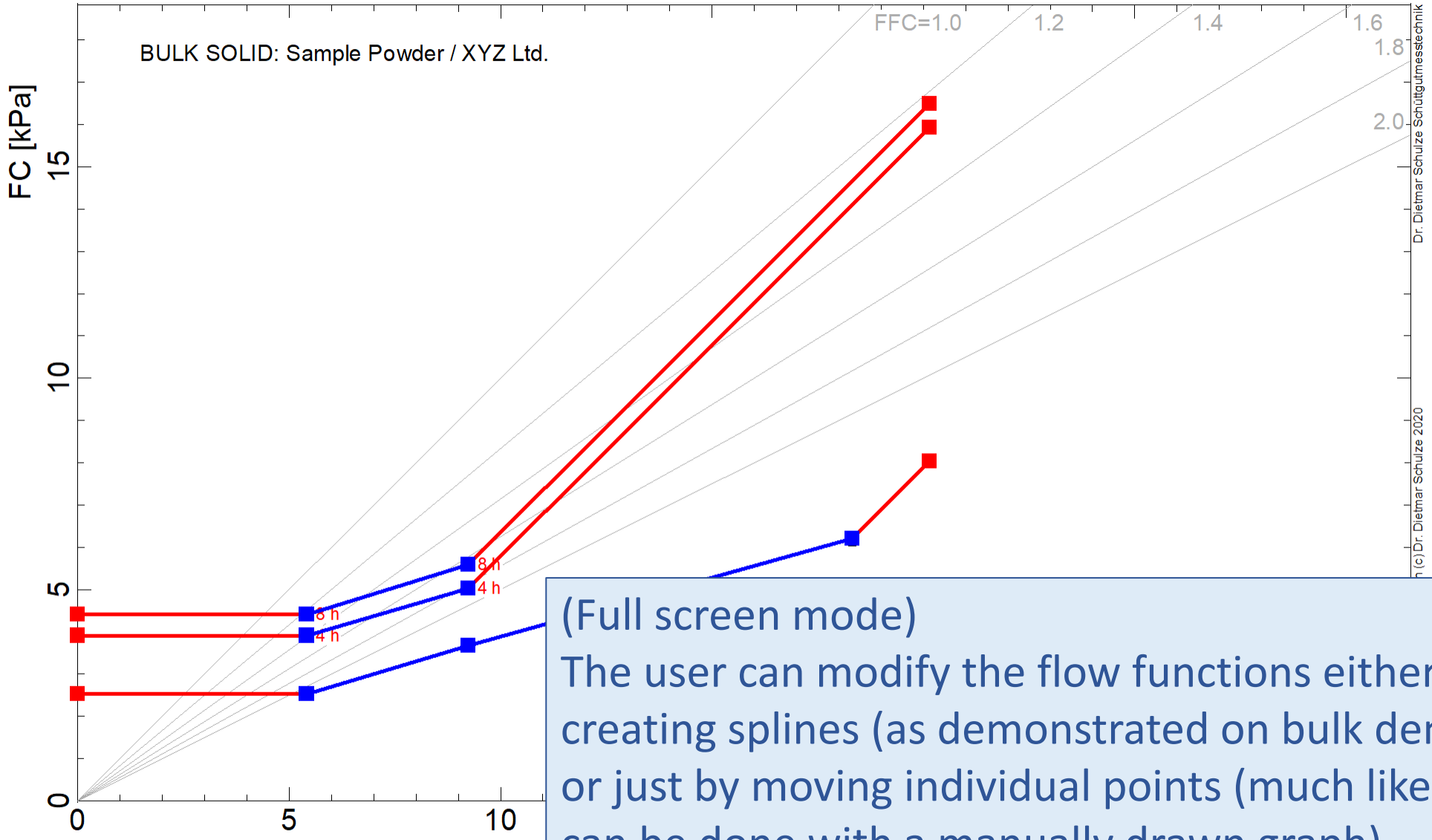
Hopper shape
- Cone
- Wedge
- Asym. wedge

My Silo

Flow function and time flow functions:
Here the extrapolation is carried out in such a way that it is on the safe side.
→ horizontal line to the left
→ slope “1” to the right

Zur Suche Text hier eingeben

SIGMA1 [kPa]: 12.310 FC [kPa]: -3.781 Error approx. [kPa]: 0.0176 FFC = SIGMA1/FC: Screen coordinates: [808;1411]

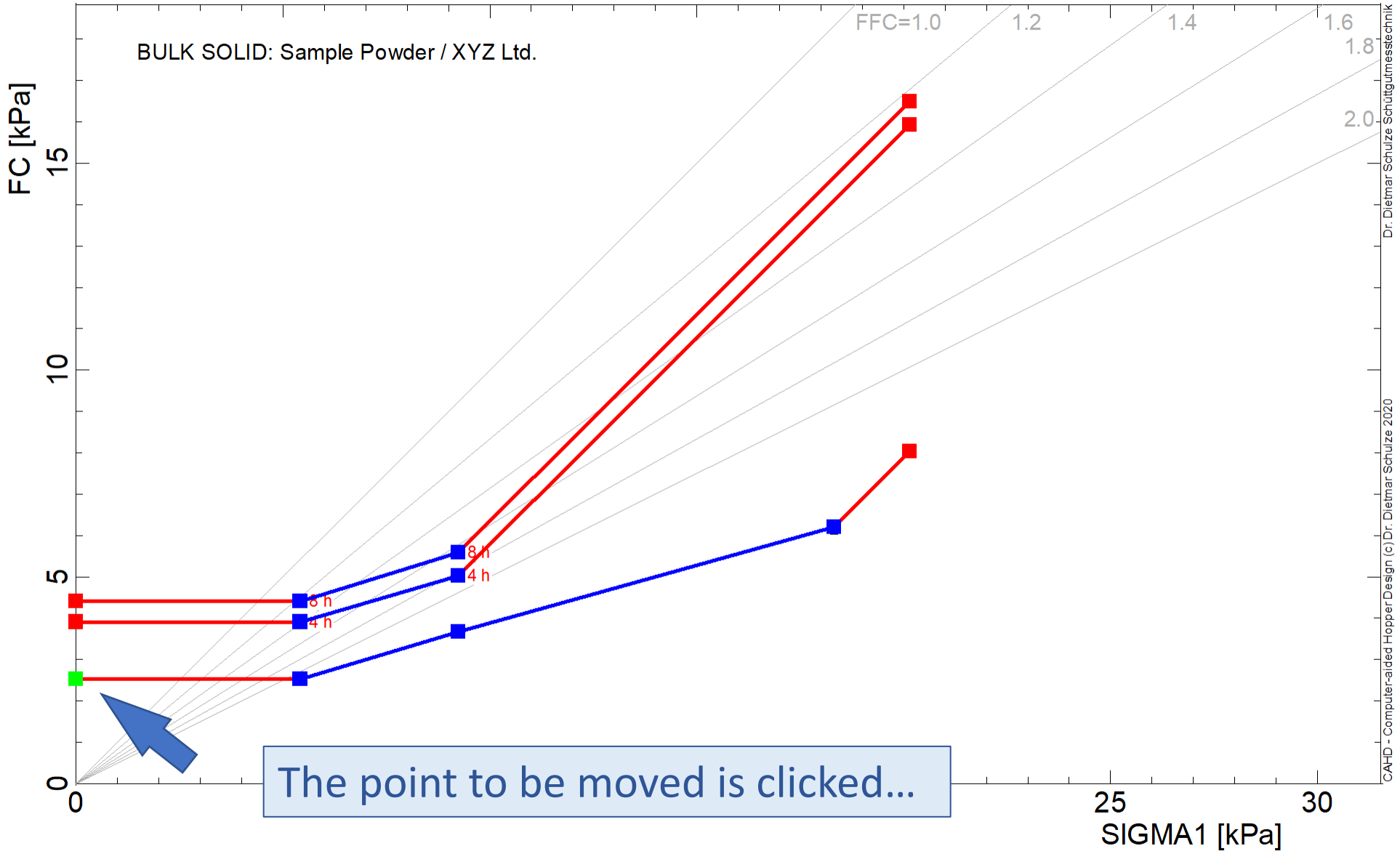


(Full screen mode)
The user can modify the flow functions either by creating splines (as demonstrated on bulk density) or just by moving individual points (much like what can be done with a manually drawn graph).

Zoom: Right click.

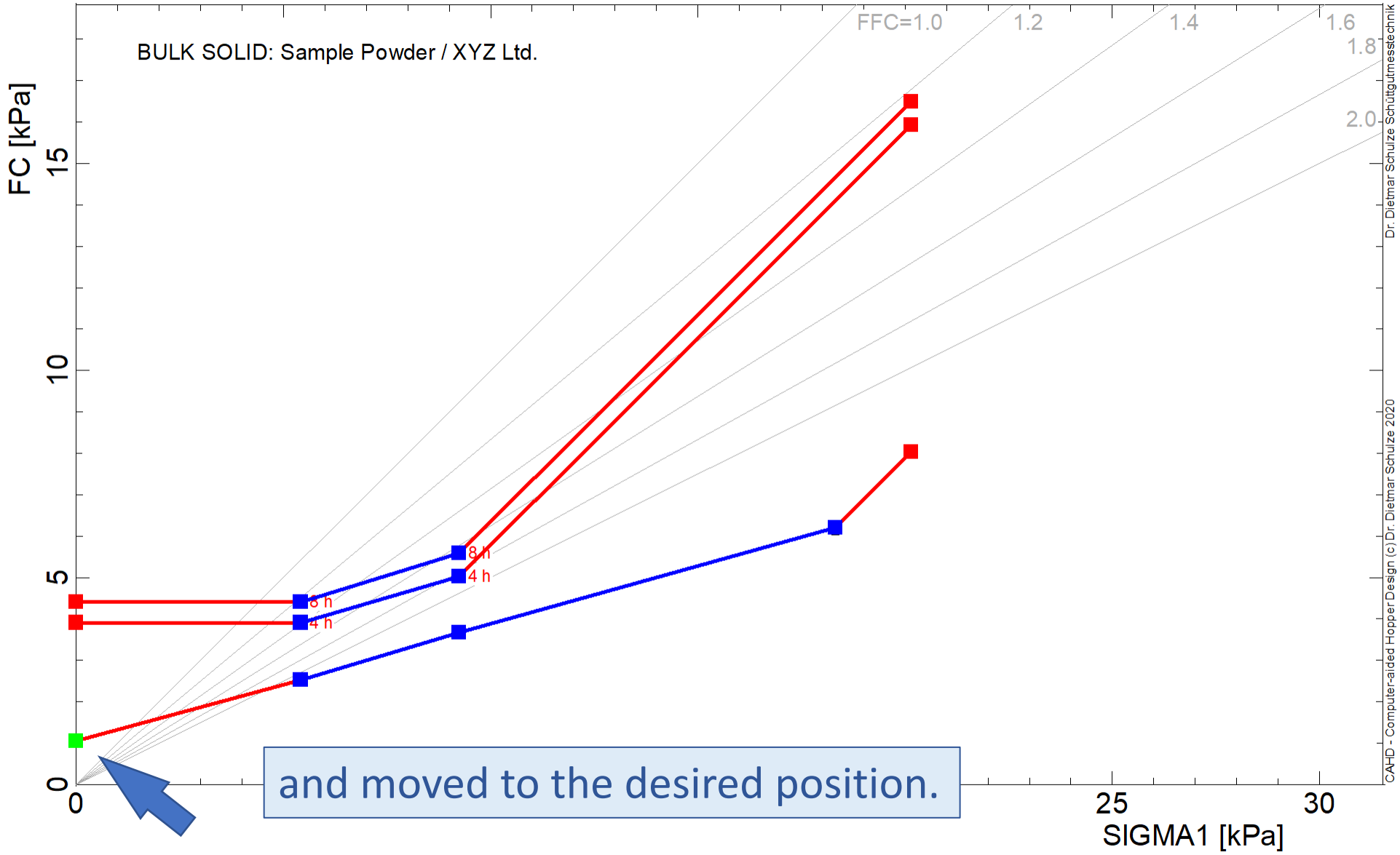
Close

SIGMA1 [kPa]: 13.118 FC [kPa]: -3.675 Error approx. [kPa]: 0.0176 FFC = SIGMA1/FC: Screen coordinates: [854;1405]



Close

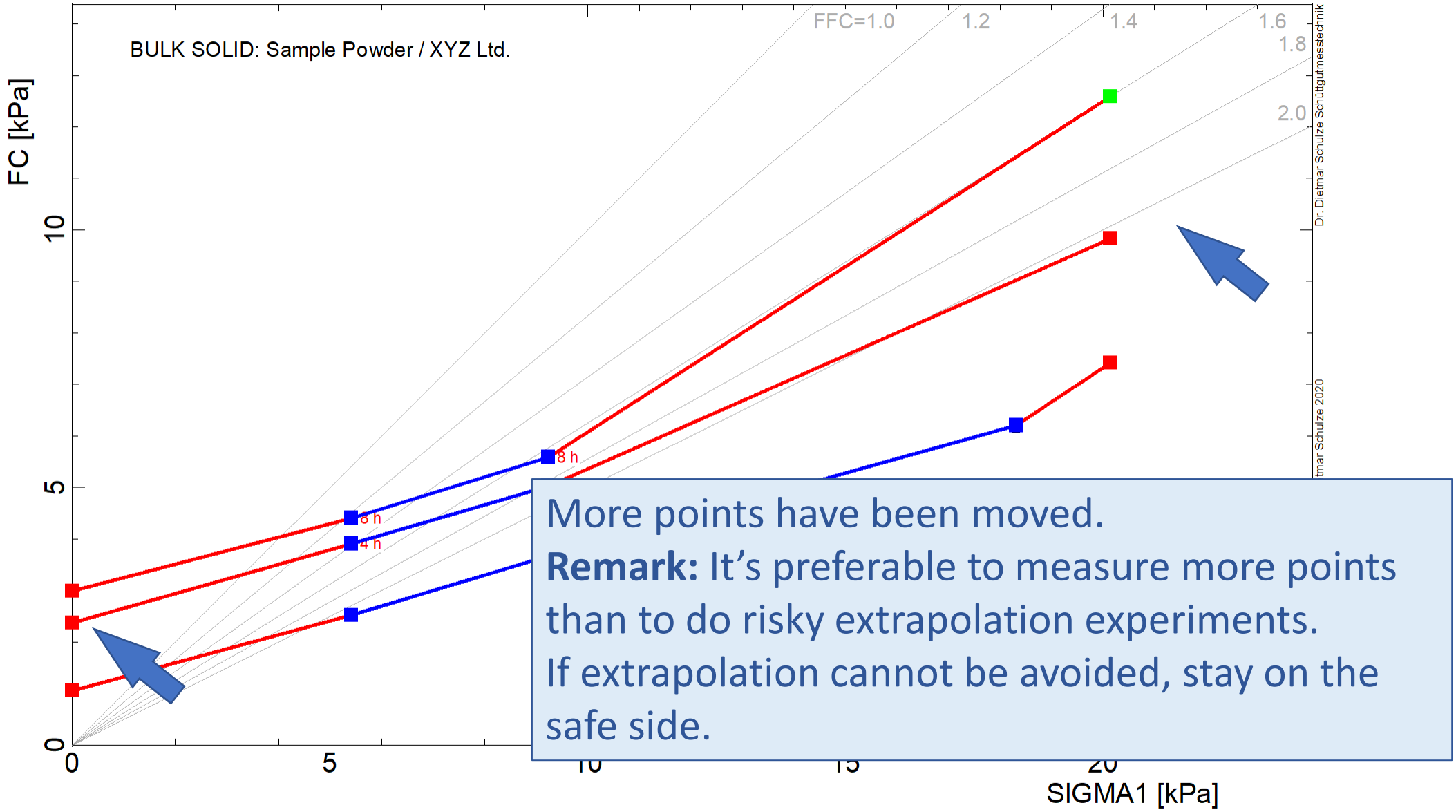
SIGMA1 [kPa]: 25.165 FC [kPa]: -3.781 Error approx. [kPa]: 0.0176 FFC = SIGMA1/FC: Screen coordinates: [1540;1411]



and moved to the desired position.

Close

SIGMA1 [kPa]: 11.542 FC [kPa]: -2.833 Error approx. [kPa]: 0.0134 FFC = SIGMA1/FC: Screen coordinates: [968;1407]



More points have been moved.
Remark: It's preferable to measure more points than to do risky extrapolation experiments.
If extrapolation cannot be avoided, stay on the safe side.

Close

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] | b, d [m]

Hopper shape

- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

CREATE PDF

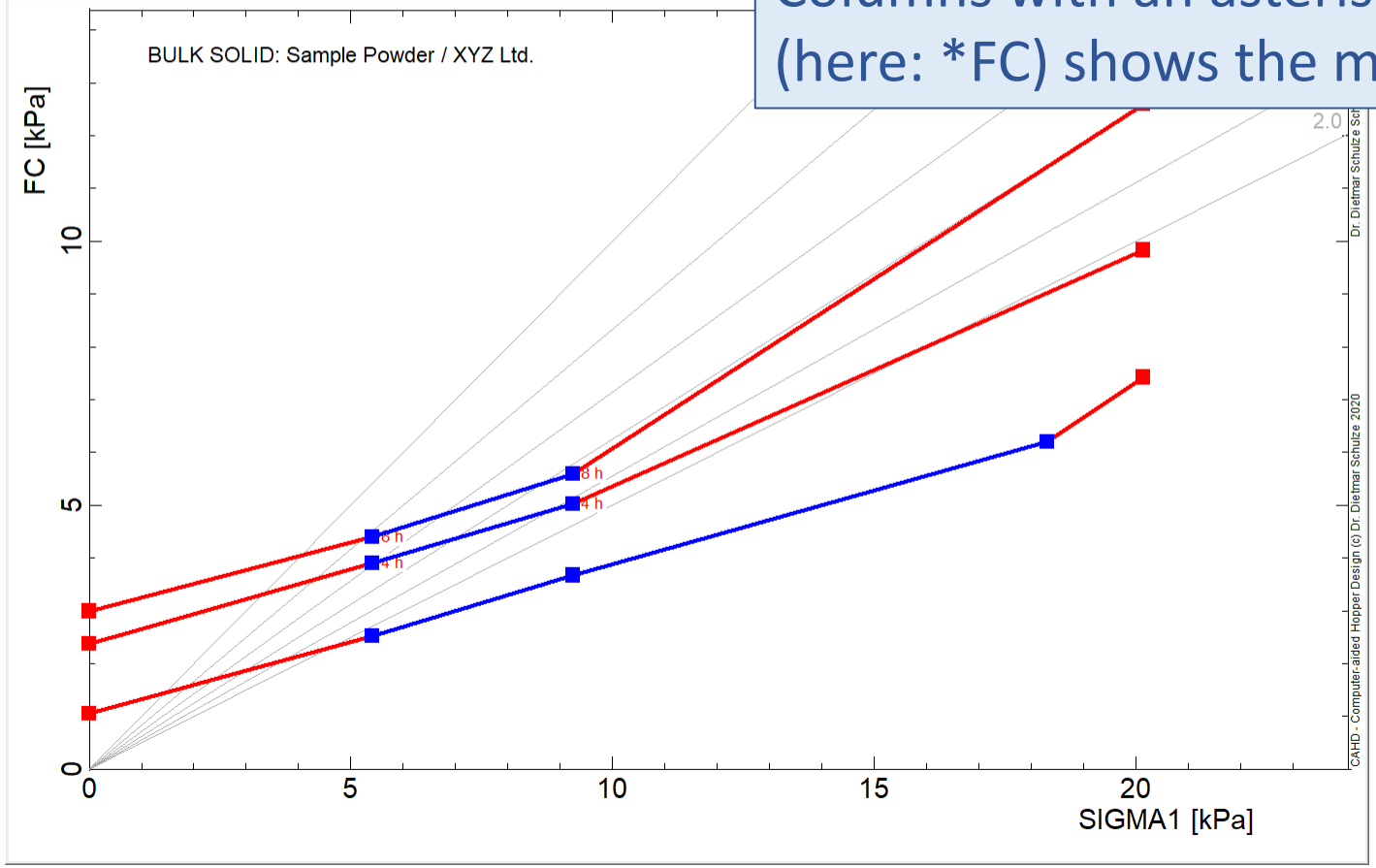
Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	1.055	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	7.421	1211	1211	45.3	45.3	36.7	36.7

Columns with an asterisk in the column header (here: *FC) shows the modified values.

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower)



Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h
- 8.00 h
- -
- -
- -
- -
- -
- -
- -
- -

My Silo

Zur Suche Text hier eingeben

CAHD [C:\Users\Public\Documents\CAHDv1\HopperDesignProjects\test.HDP]

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3.0 | ff (MF) 1

My Silo (data input)

Theta [°] | b, d [m]

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

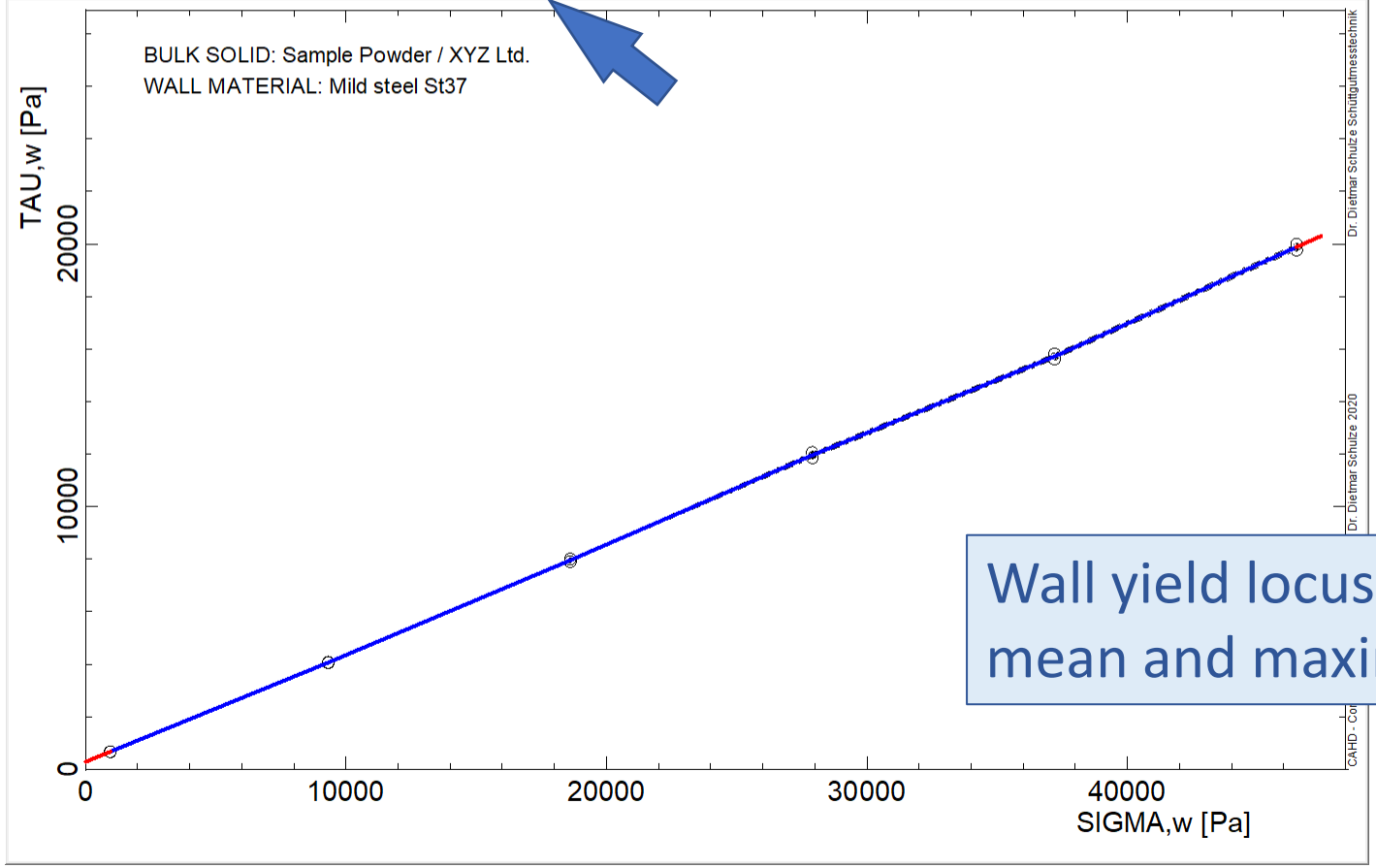
SIGMA,w [Pa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	*PHIX [°]
10	87.9	88.0	88.0	88.0
955	34.7	34.9	35.1	34.9
9320	23.5	23.6	23.6	23.6
18613	23.0	23.1	23.3	23.1
27907	23.0	23.2	23.4	23.2

Vertical wall (asymm.)

No entry: PHIXV = PHIX

PHIXV [°]

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h
- 8.00 h
- -
- -
- -
- -

My Silo

Wall yield locus and table with minimum, mean and maximum wall friction angles

Zur Suche Text hier eingeben

CAHD [C:\Users\Public\Documents\CAHDv1\HopperDesignProjects\test.HDP]

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3.0 | ff (MF) 1

My Silo (data input)

Theta [°] | b, d [m]

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

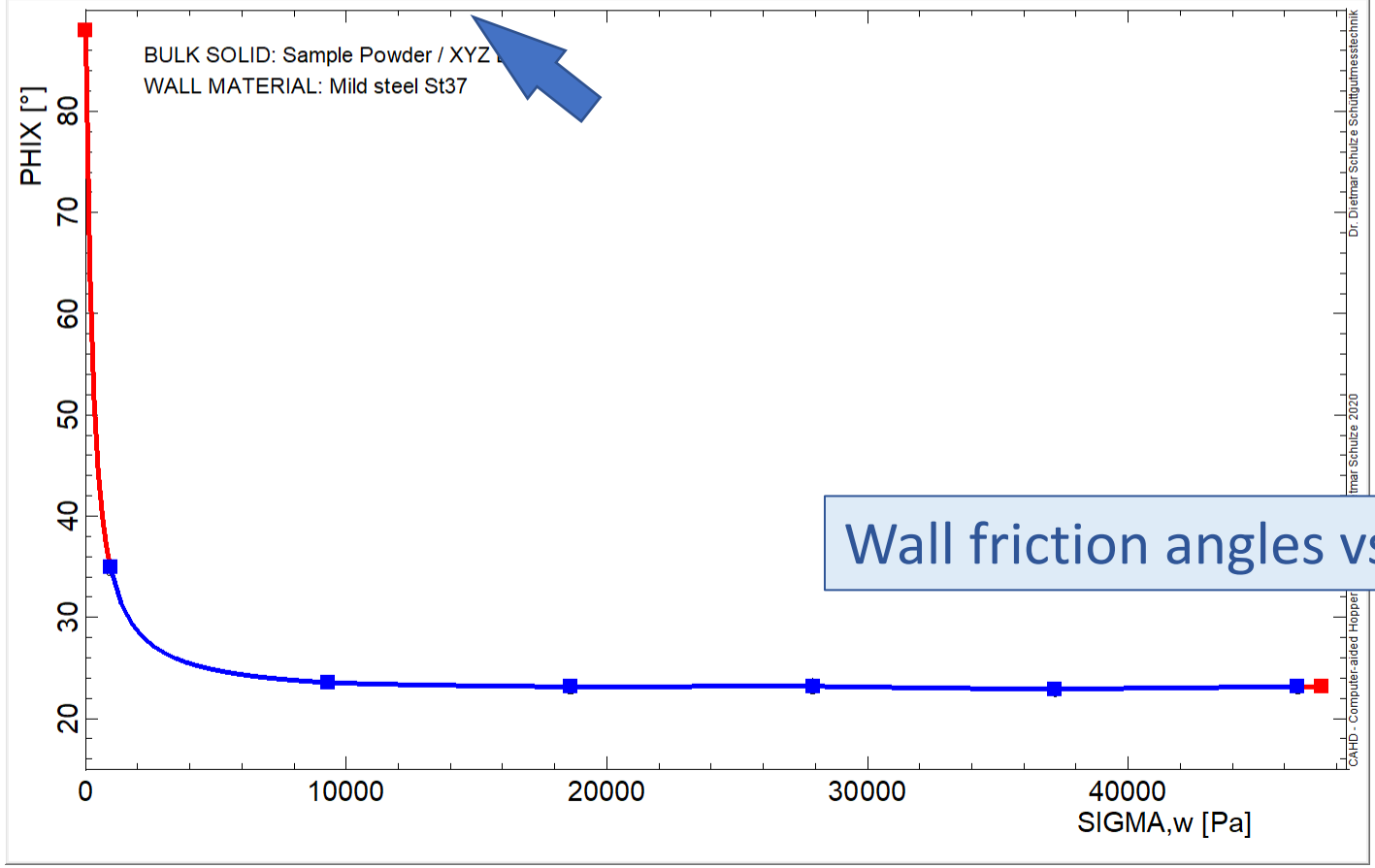
SIGMA,w [Pa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	*PHIX [°]
10	87.9	88.0	88.0	88.0
955	34.7	34.9	35.1	34.9
9320	23.5	23.6	23.6	23.6
18613	23.0	23.1	23.3	23.1
27907	23.0	23.2	23.4	23.2

Vertical wall (asymm.)

No entry: PHIXV = PHIX

PHIXV [°]

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Wall friction angles vs. wall normal stress

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

[ ] My Silo

Zur Suche Text hier eingeben

CAHD [C:\Users\Public\Documents\CAHDv1\HopperDesignProjects\test.HDP]

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3.0 | ff (MF) 1

My Silo (data inp...

Theta [°] | b, d [m]

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

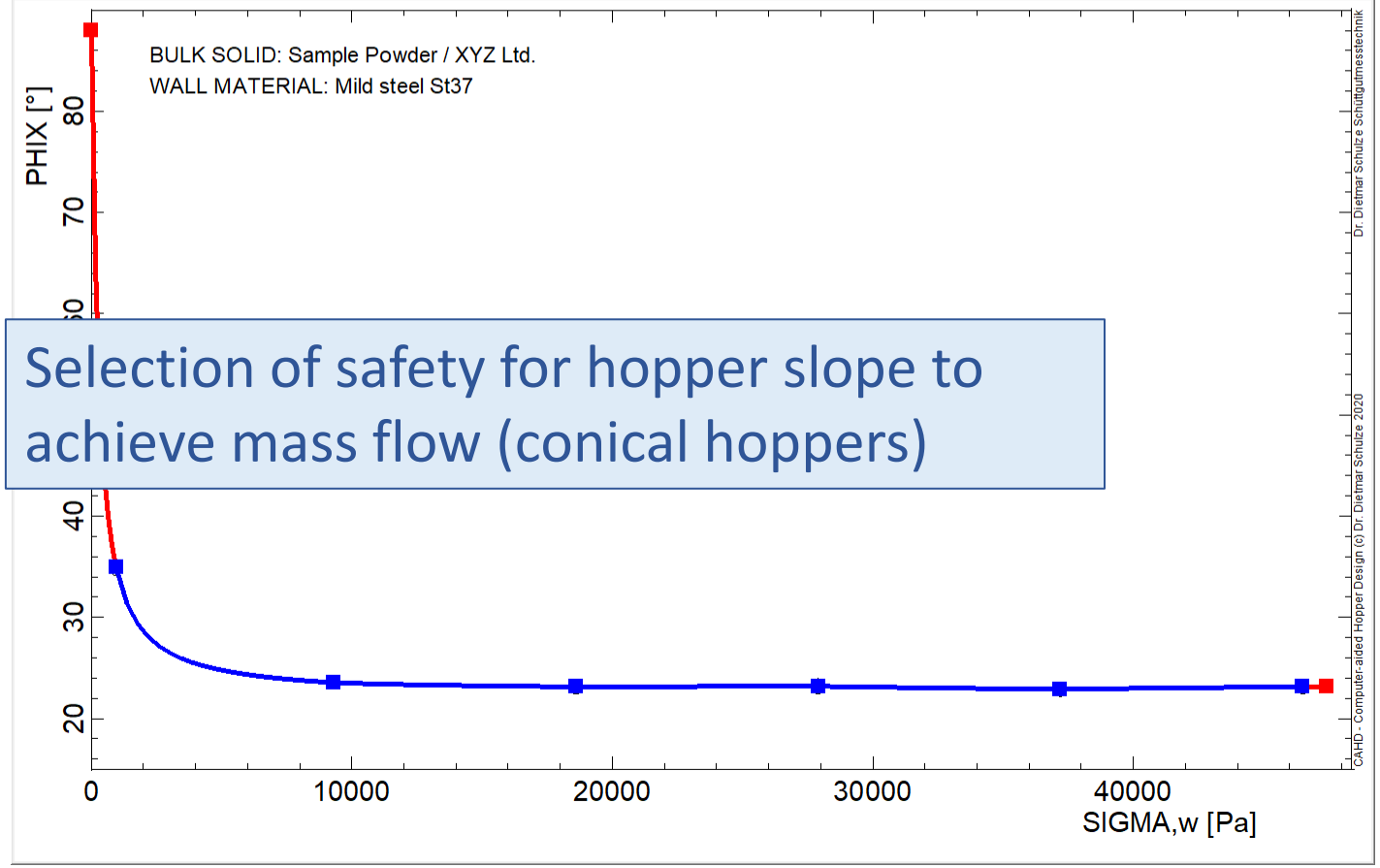
SIGMA,w [Pa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	*PHIX [°]
10	87.9	88.0	88.0	88.0
955	34.7	34.9	35.1	34.9
9320	23.5	23.6	23.6	23.6
18613	23.0	23.1	23.3	23.1
27907	23.0	23.2	23.4	23.2

Vertical wall (asymm.)

No entry: PHIXV = PHIX

PHIXV [°]

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Selection of safety for hopper slope to achieve mass flow (conical hoppers)

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD [C:\Users\Public\Documents\CAHDv1\HopperDesignProjects\test.HDP]

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3.0 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

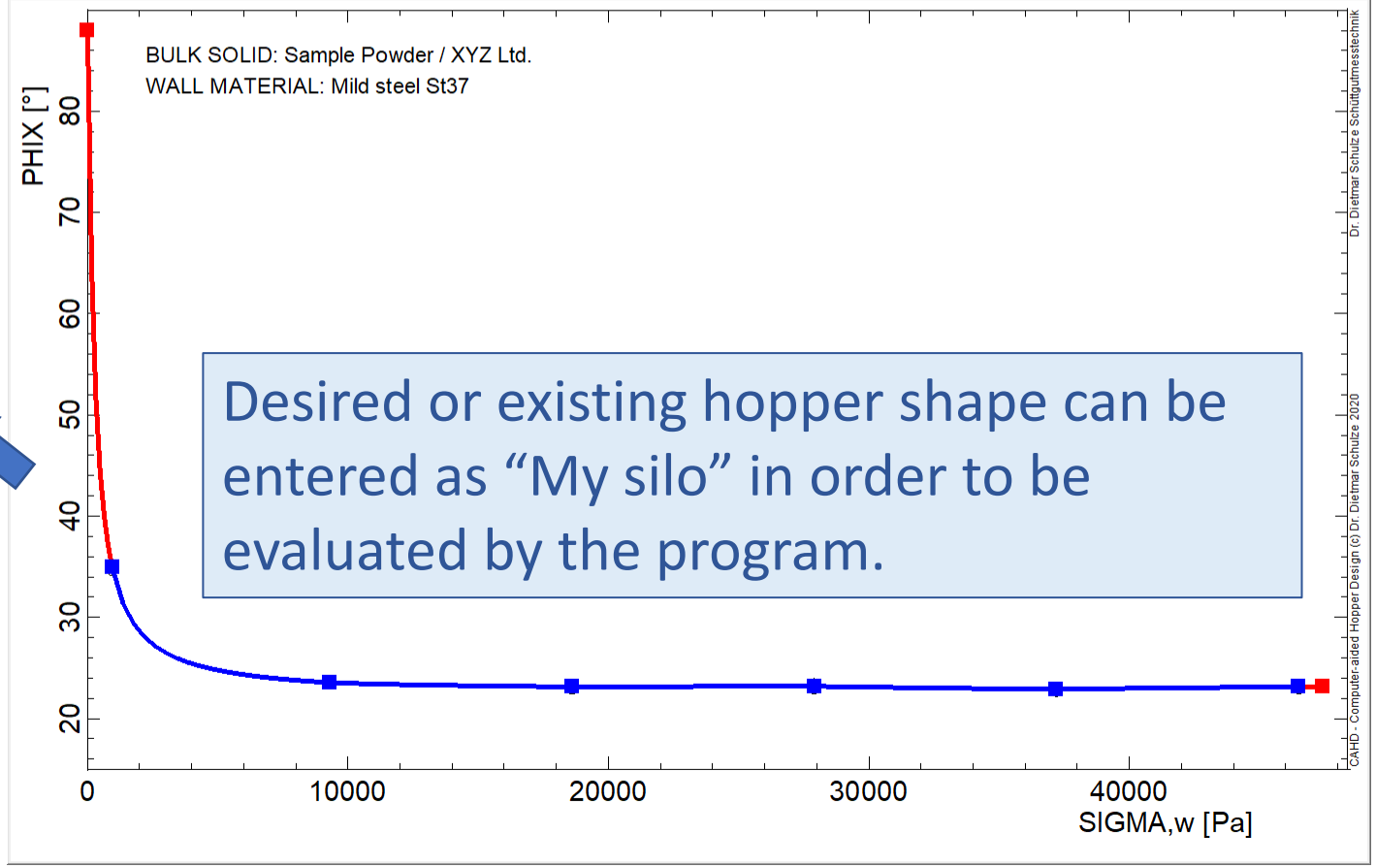
SIGMA,w [Pa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	*PHIX [°]
10	87.9	88.0	88.0	88.0
955	34.7	34.9	35.1	34.9
9320	23.5	23.6	23.6	23.6
18613	23.0	23.1	23.3	23.1
27907	23.0	23.2	23.4	23.2

Vertical wall (asymm.)

No entry: PHIXV = PHIX

PHIXV [°]

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Desired or existing hopper shape can be entered as “My silo” in order to be evaluated by the program.

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] 20 b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

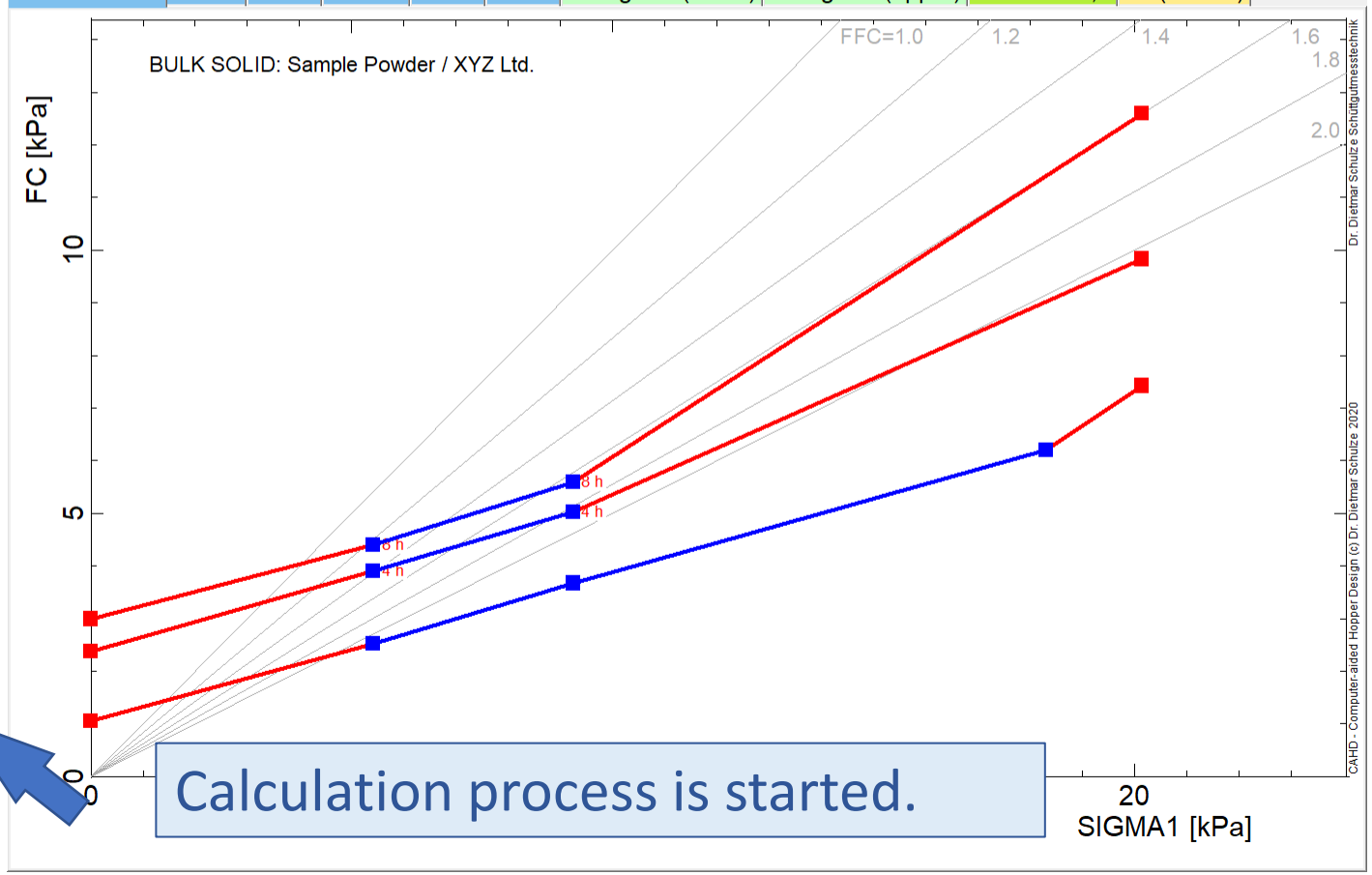
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	1.055	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	7.421	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Calculation process is started.

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

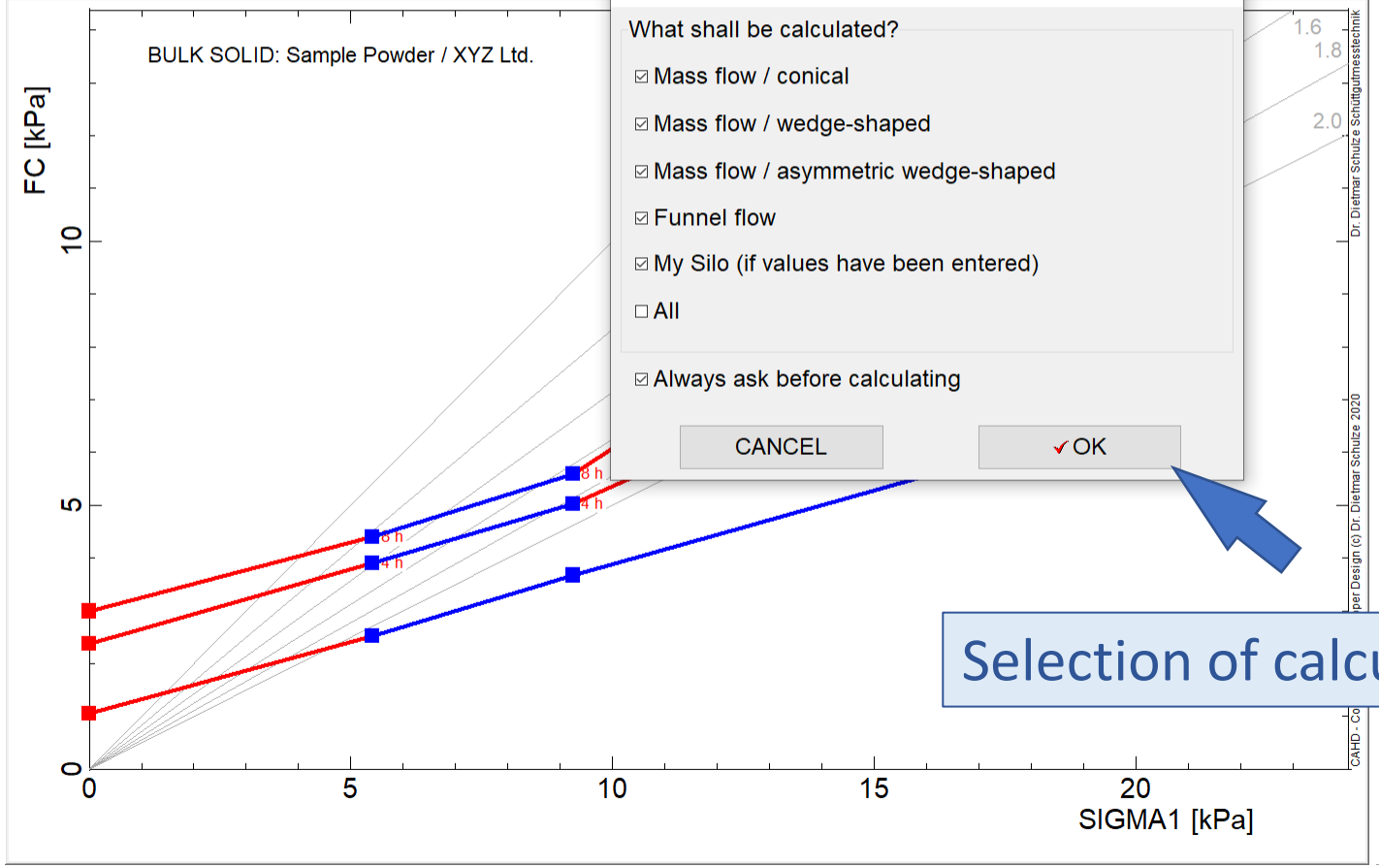
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	1.055	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	7.421	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Selection of quantities for calculation

What shall be calculated?

- ☑ Mass flow / conical
- ☑ Mass flow / wedge-shaped
- ☑ Mass flow / asymmetric wedge-shaped
- ☑ Funnel flow
- ☑ My Silo (if values have been entered)
- ☐ All

☑ Always ask before calculating

CANCEL | ✓OK

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile

- (•) Mass flow
- ( ) Funnel flow

Crit. values

- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Selection of calculations.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

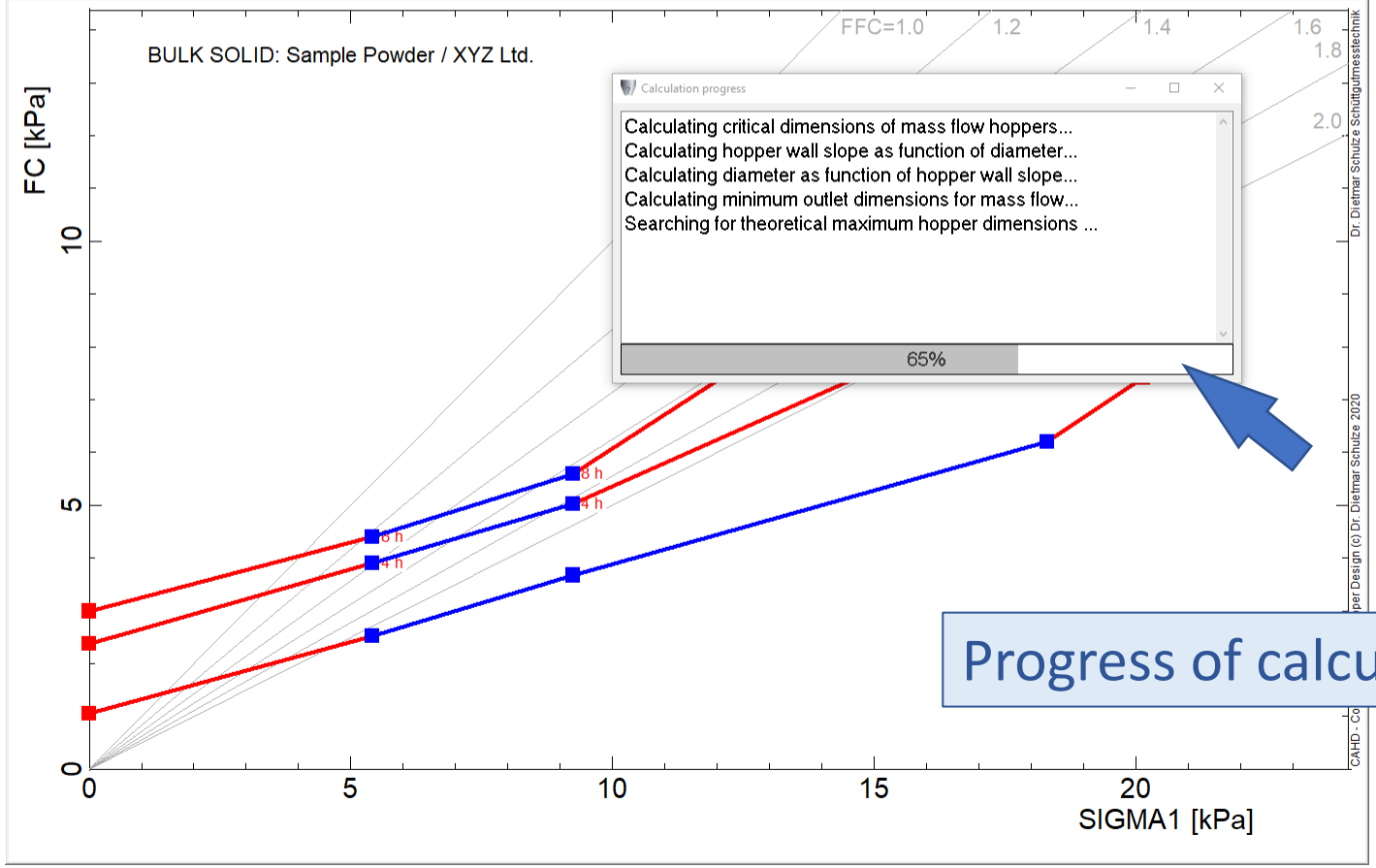
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

SIGMA1 [kPa]	FC [kPa]	*FC [kPa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0.000	2.523	1.055	811	811	56.1	56.1	40.6	40.6
5.417	2.523	2.523	1066	1066	51.2	51.2	38.6	38.6
9.239	3.671	3.671	1114	1114	47.8	47.8	37.1	37.1
18.315	6.205	6.205	1195	1195	45.7	45.7	36.8	36.8
20.147	8.037	7.421	1211	1211	45.3	45.3	36.7	36.7

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Progress of calculation process

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] 20 b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

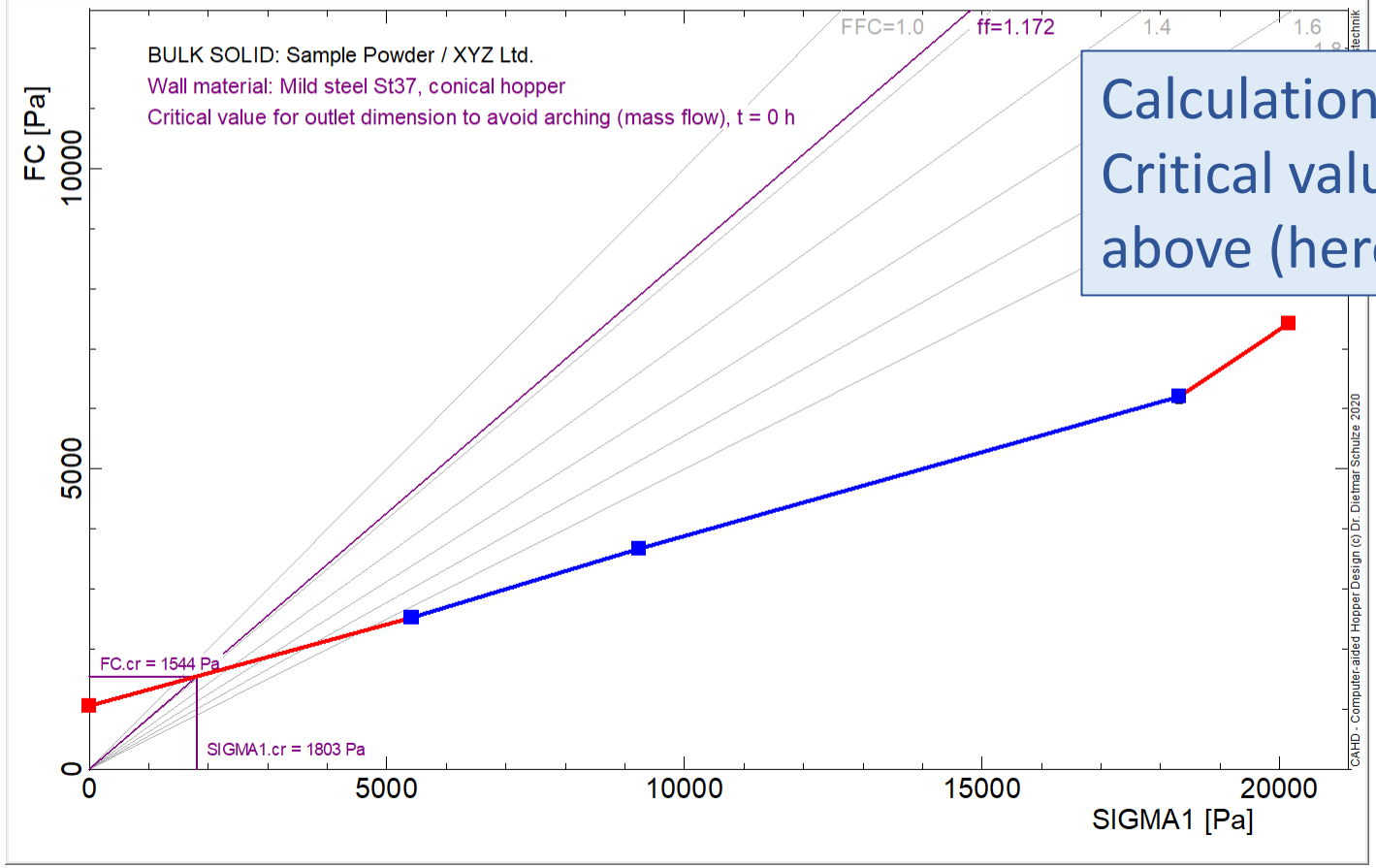
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape

- (•) Cone
- ( ) Wedge

( ) No (all)
(•) t = 0
( ) 4.00 h
( ) 8.00 h
( ) -
( ) -
( ) -
( ) -
( ) -
( ) -
( ) -
( ) -

☐ My Silo

Calculation is done.
Critical values are given in the tables above (here: conical hopper).

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

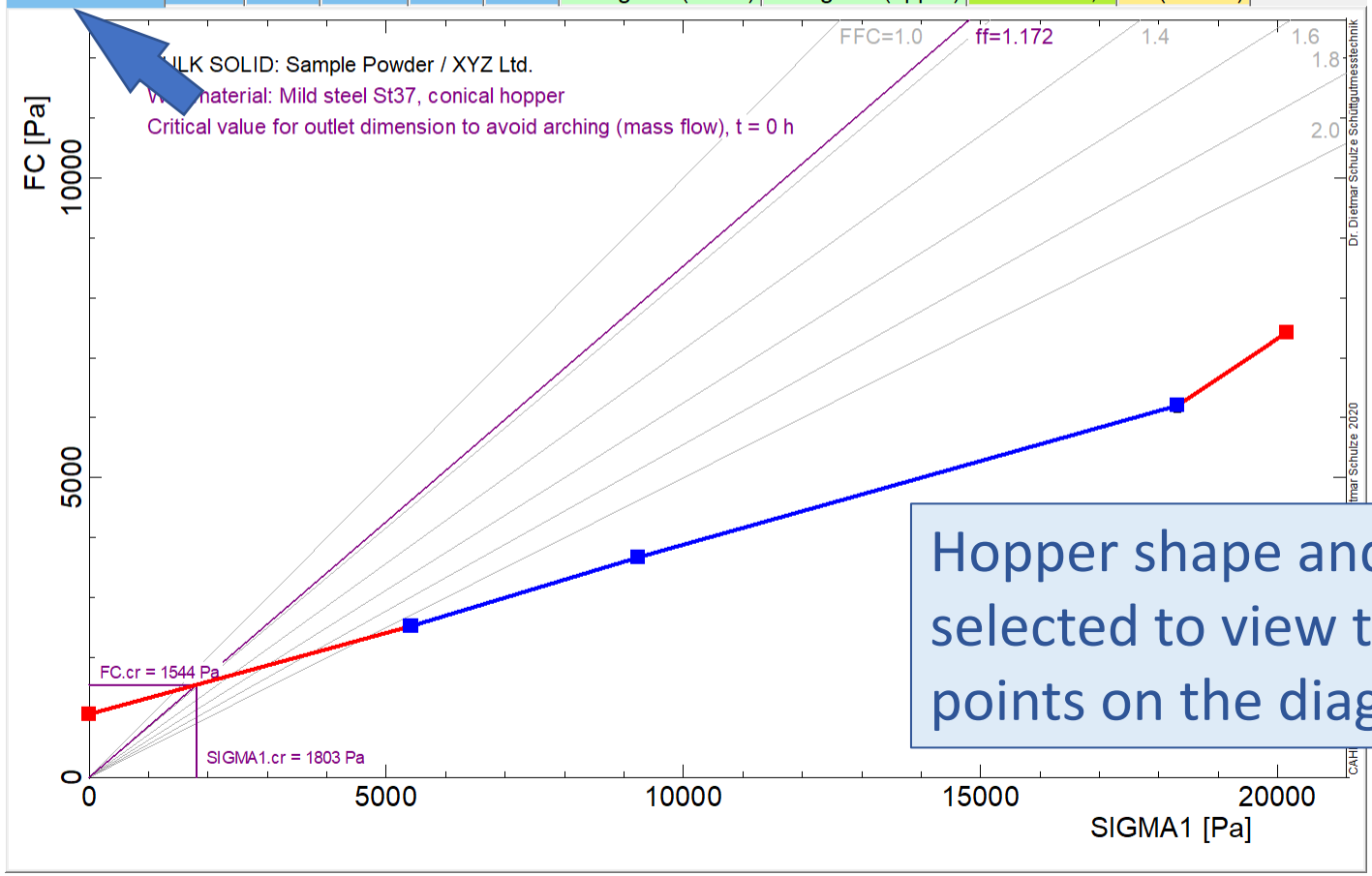
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h
- 8.00 h
- -

□ My Silo

Hopper shape and storage time can be selected to view the associated critical points on the diagrams (here: flow function)

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

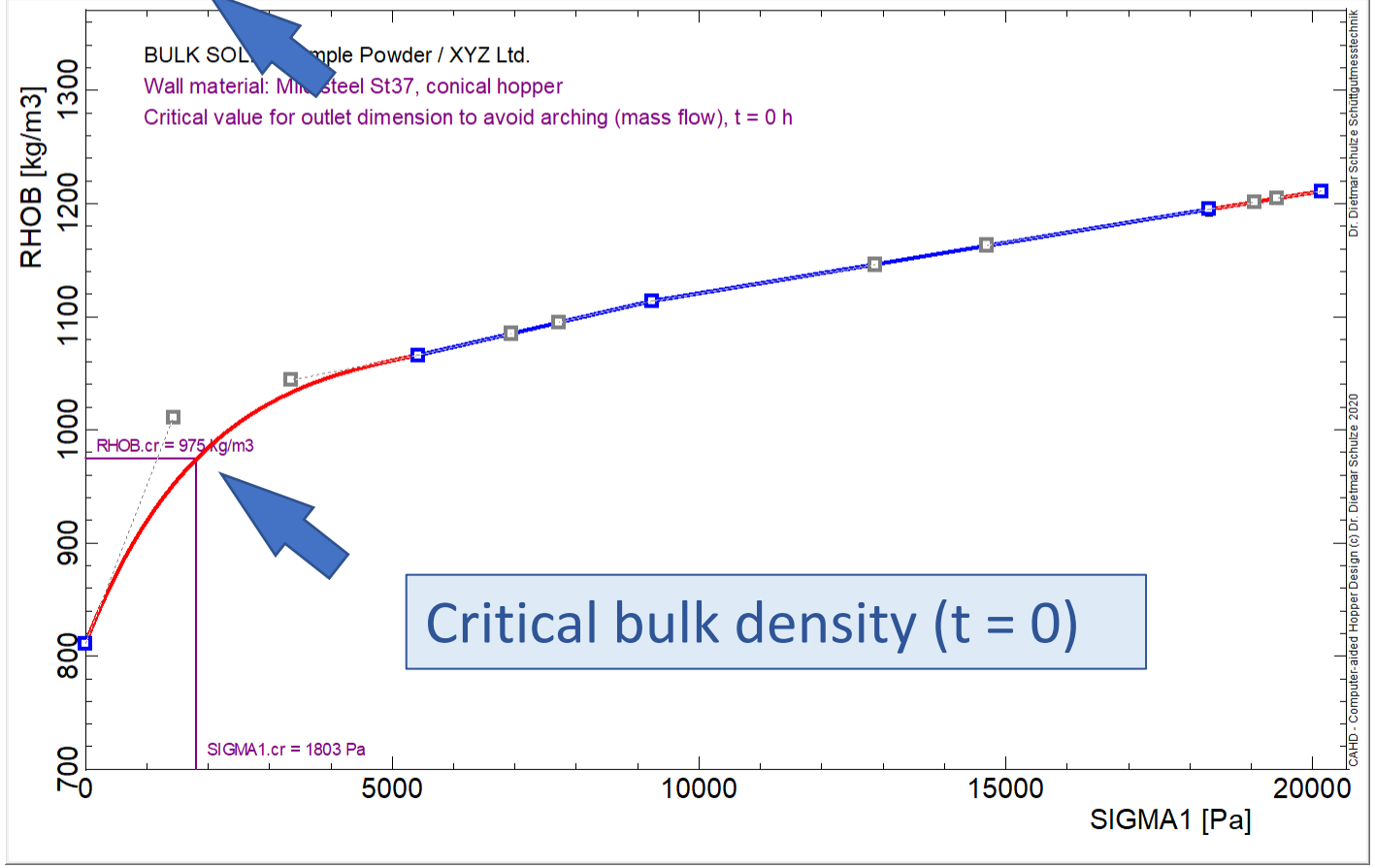
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- ( ) No (all)
- (•) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

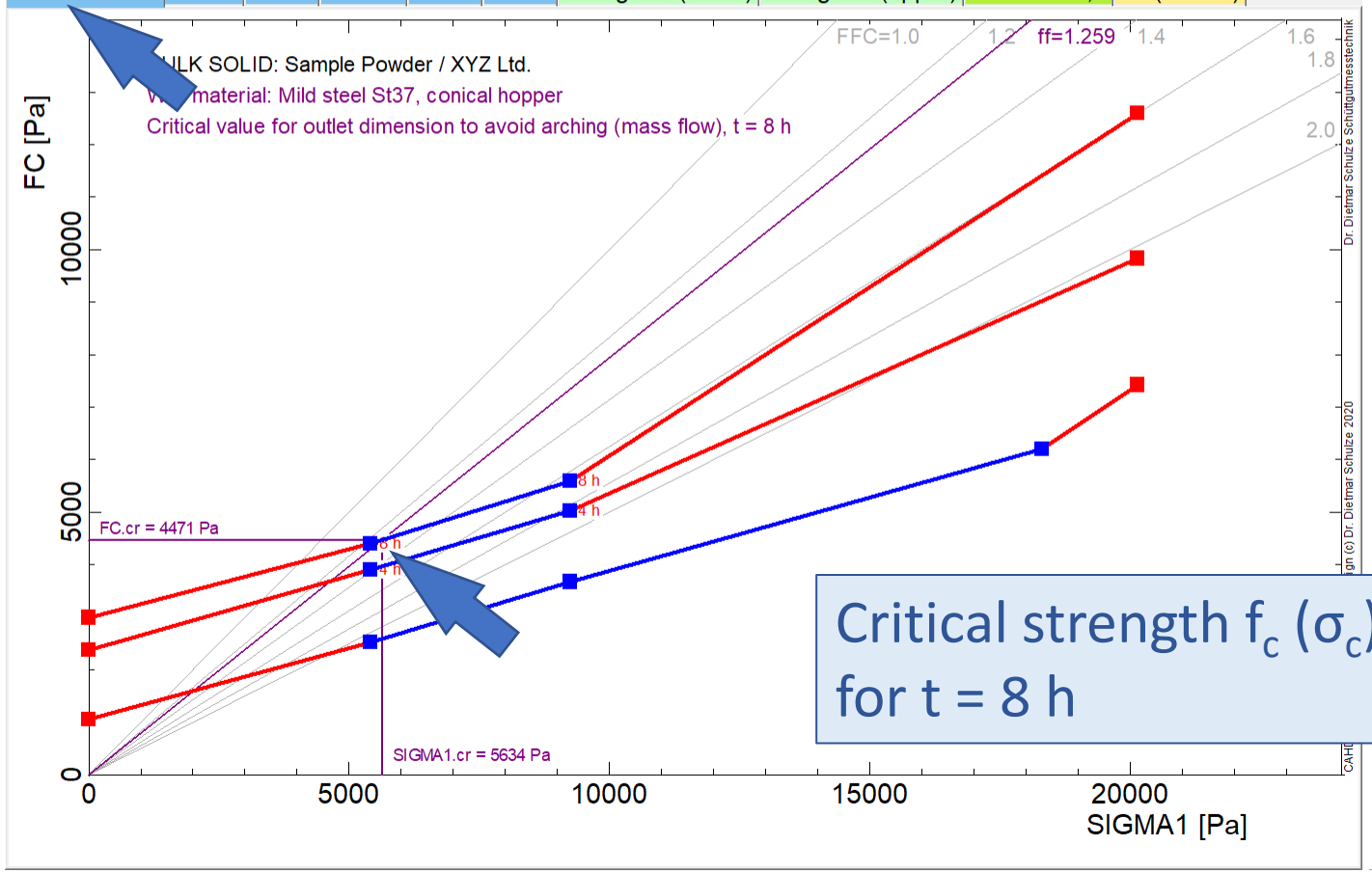
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Critical strength f_c (σ_c) for t = 8 h

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- ( ) No (all)
- ( ) t = 0
- ( ) 4.00 h
- (•) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File | Test data | Actual diagram | Actual Table | Tools | Preferences | Admin | Help | Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

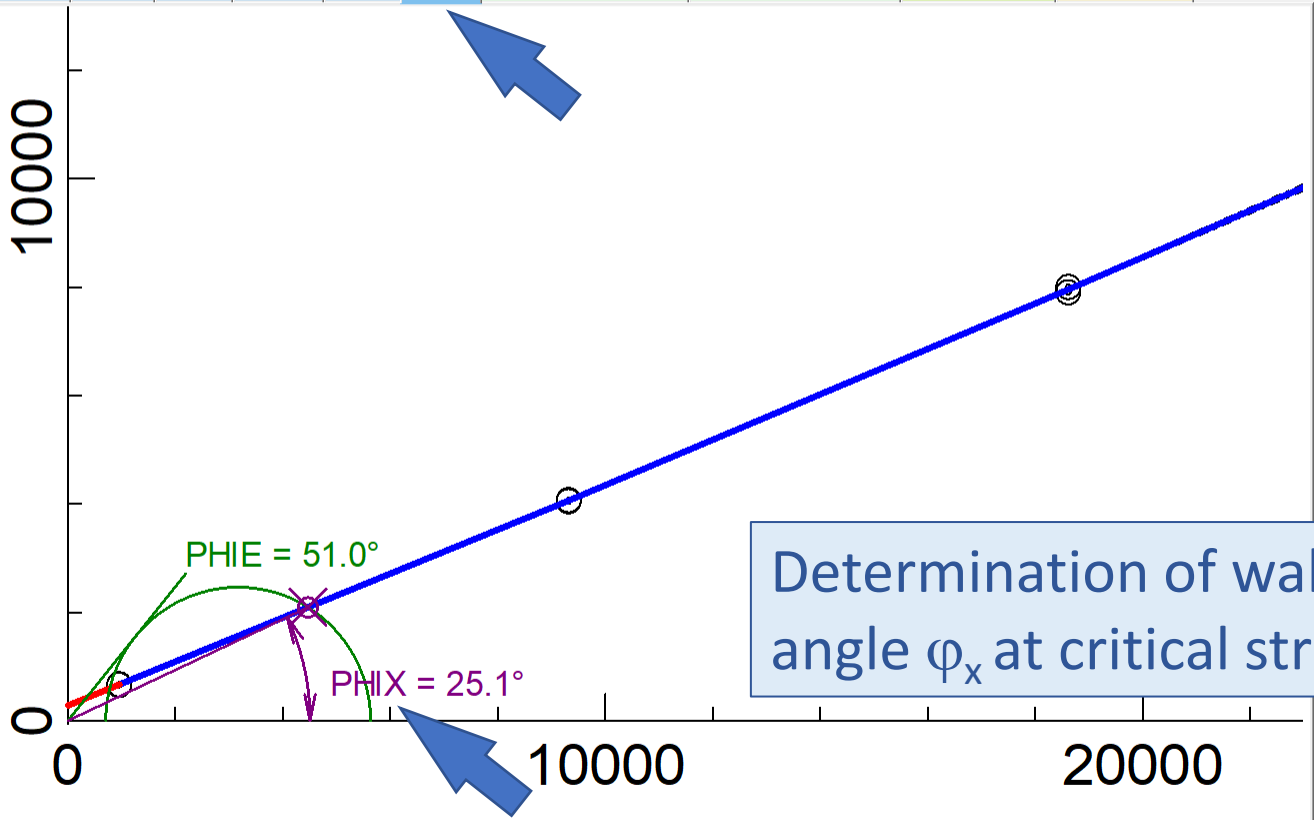
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Determination of wall friction angle φ_x at critical stress (t = 8 h)

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- ( ) No (all)
- ( ) t = 0
- ( ) 4.00 h
- (•) 8.00 h
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

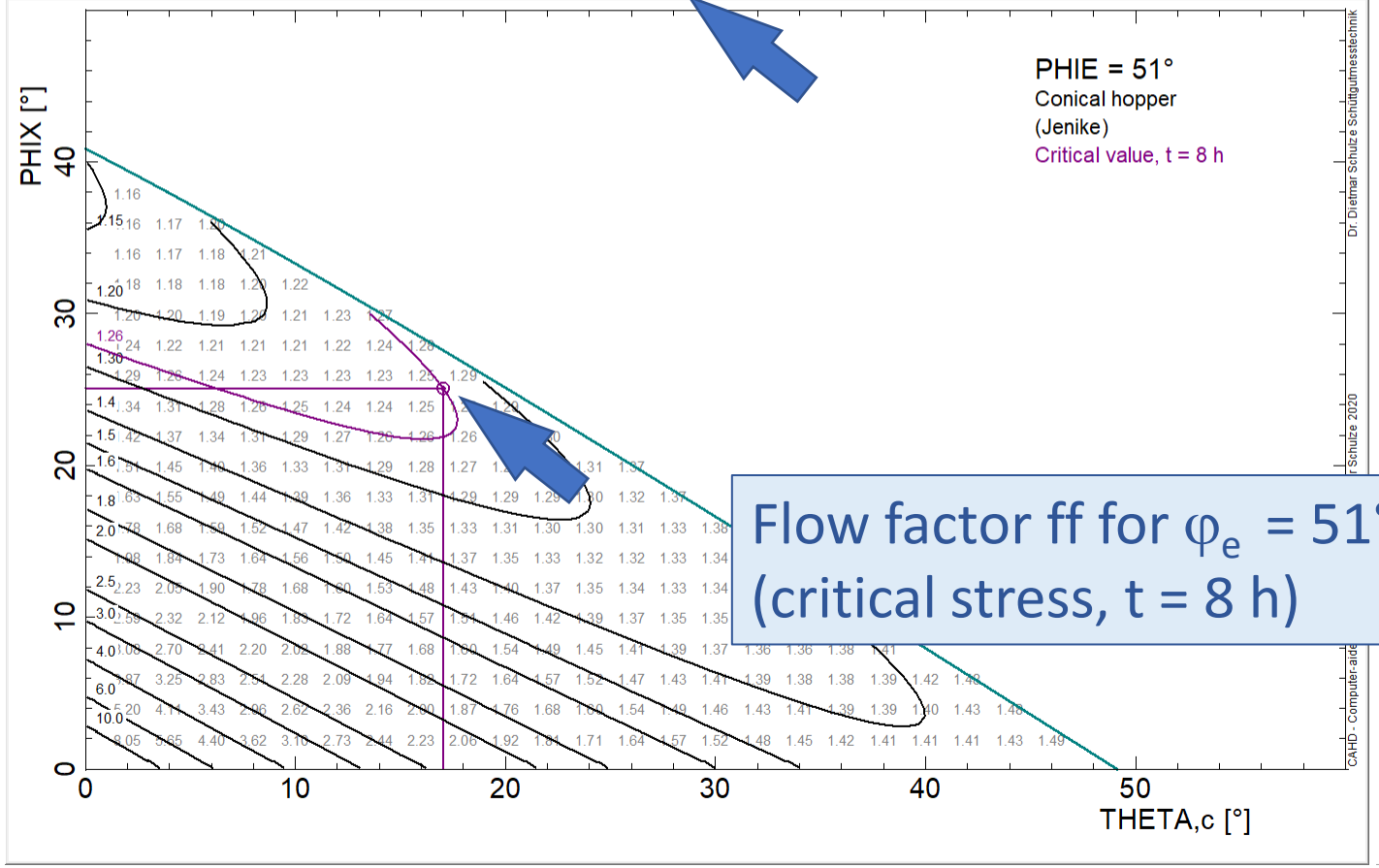
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Flow factor ff for φ_e = 51° (critical stress, t = 8 h)

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- ( ) No (all)
- ( ) t = 0
- ( ) 4.00 h
- (•) 8.00 h
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

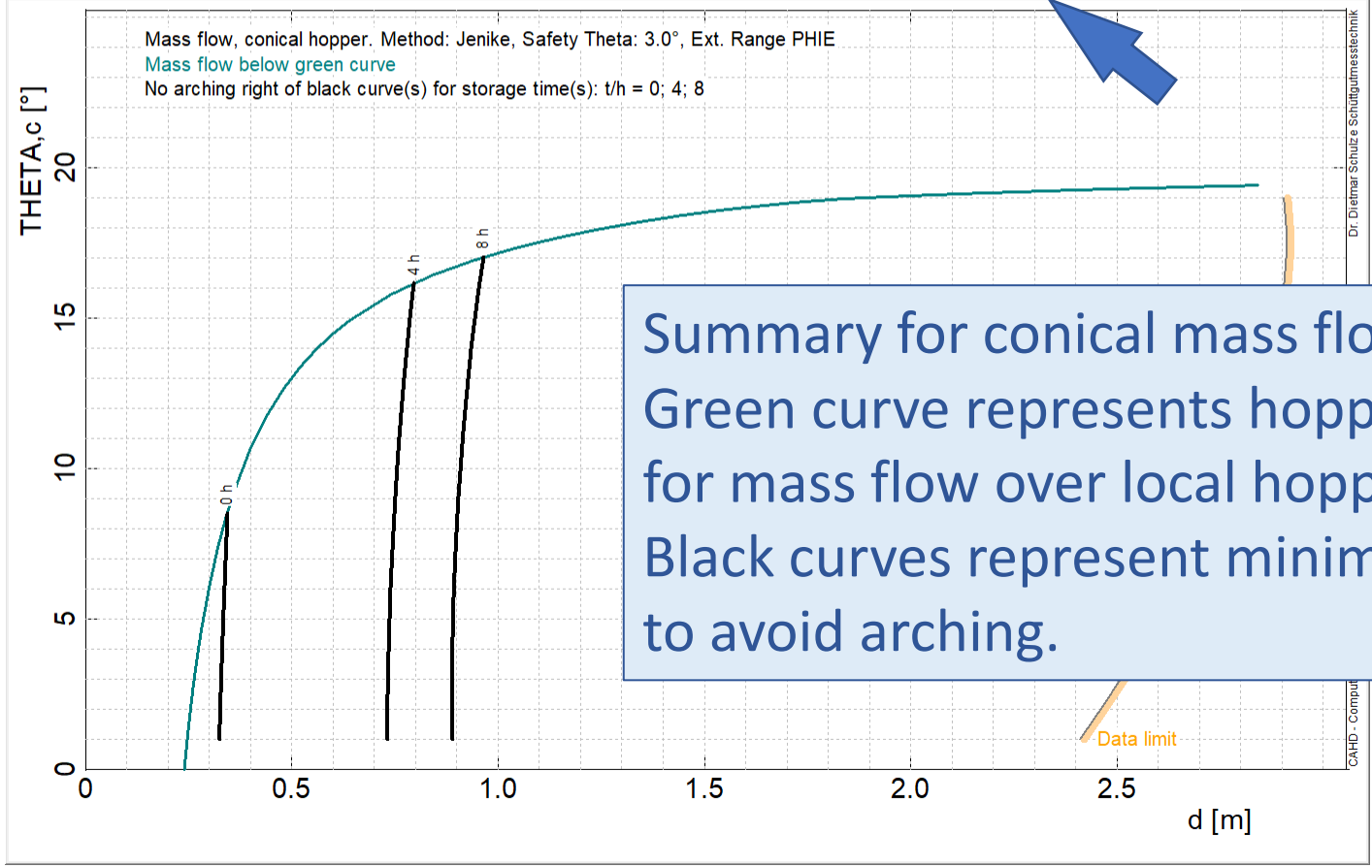
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]	Comment
0	1803	1223	1544	975	54.4	32.4	39.9	**8.5**	1.172	2.13	**0.344**	0.145	608	
4.00	4564	3576	3666	1056	52.0	25.8	38.9	**16.2**	1.244	2.25	**0.796**	0.155	1626	
8.00	5634	4469	4471	1069	51.0	25.1	38.5	**17.0**	1.259	2.26	**0.964**	0.158	2033	

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Summary for conical mass flow hopper:
Green curve represents hopper slope Θ_c (THETA,c) for mass flow over local hopper diameter d.
Black curves represent minimum outlet diameters to avoid arching.

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values

- -
- -

□ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

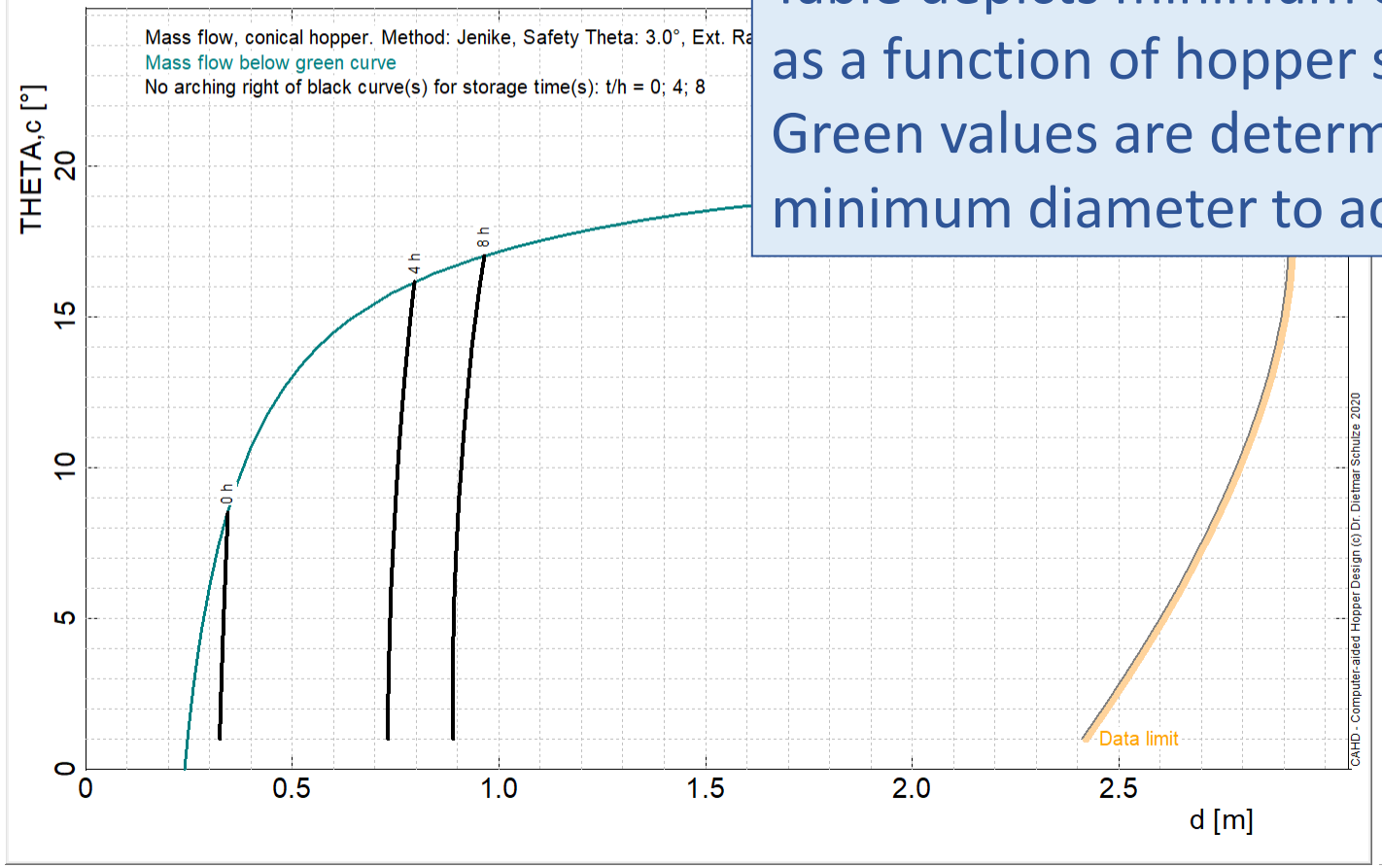
Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Theta,c [°] | t [h]	0	4.00	8.00	Unit								Comment
19.0	1.848	1.848	1.848	m								Green: Minimum dimension for mass flow
18.0	1.253	1.253	1.253	m								Green: Minimum dimension for mass flow
17.0	0.954	0.954	0.964	m								Green: Minimum dimension for mass flow
16.0	0.768	0.794	0.953	m								Green: Minimum dimension for mass flow
15.0	0.646	0.786	0.944	m								Green: Minimum dimension for mass flow

Table depicts minimum outlet diameter, d, as a function of hopper slope, Θ_c (THETA,c). Green values are determined by the minimum diameter to achieve mass flow.

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower



Crit. values

- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

☐ My Silo

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 ff (MF) 1

My Silo (data input)

Theta [°] 20 b, d [m] 0.5

Hopper shape

- Cone
- Wedge
- Asym. wedge

More settings

CALCULATE

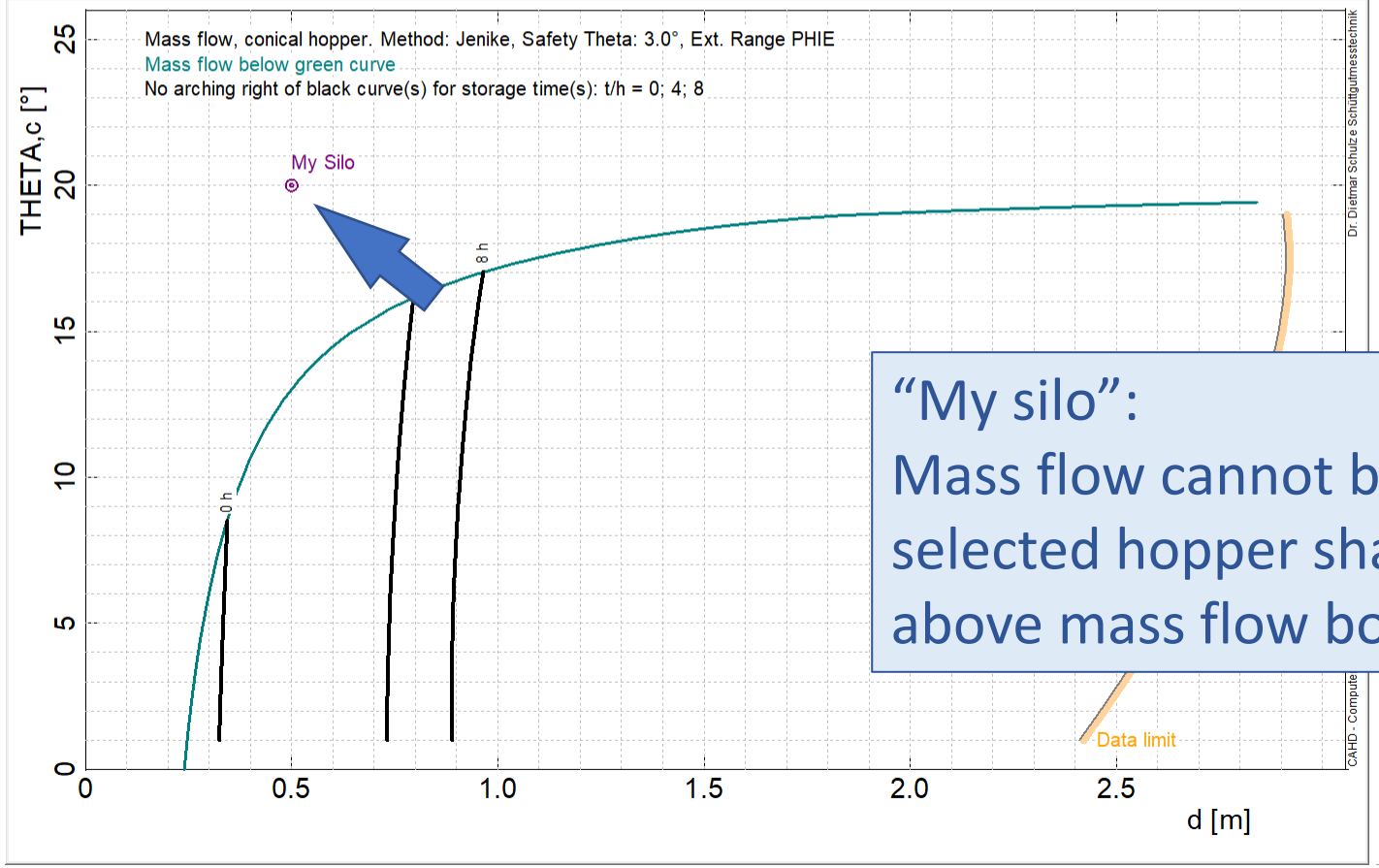
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN [°]	Theta,c [°]	ff [-]	d [m]	q [-]	SIGMAV,cr [Pa]	Comment
0								20.0		0.500			No mass flow
4.00								20.0		0.500			No mass flow
8.00								20.0		0.500			No mass flow

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- -
- -

☑ My Silo

"My silo":
Mass flow cannot be achieved with the selected hopper shape: Point "My silo" lies above mass flow boundary on the diagram.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- Cone
- Wedge
- Asym.

More

C

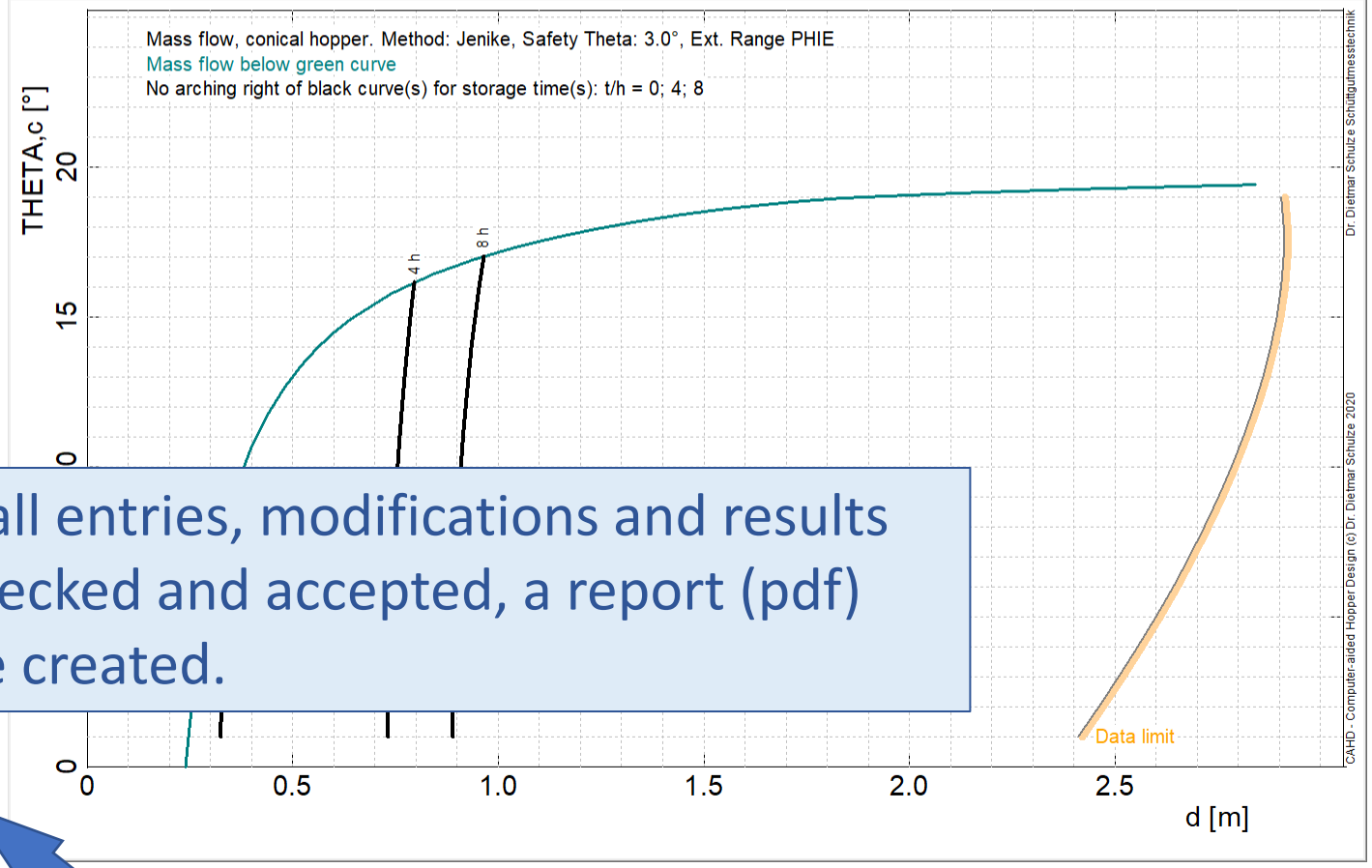
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Theta,c [°] | t [h]	0	4.00	8.00	Unit								Comment
19.0	1.848	1.848	1.848	m								Green: Minimum dimension for mass flow
18.0	1.253	1.253	1.253	m								Green: Minimum dimension for mass flow
17.0	0.954	0.954	0.964	m								Green: Minimum dimension for mass flow
16.0	0.768	0.794	0.953	m								Green: Minimum dimension for mass flow
15.0	0.646	0.786	0.944	m								Green: Minimum dimension for mass flow

Flow function | RHOB | PHIE | PHILIN | PHIX | WYL | ff diagram (lower) | ff diagram (upper) | Theta vs. b,d | FF (LB/UB)



Hopper shape
- Cone
- Wedge
- Asym. wedge

Flow profile
- Mass flow
- Funnel flow

Crit. values
- No (all)
- t = 0
- 4.00 h
- 8.00 h
- -
- -
- -
- -
- -
- -
- -
- -

☐ My Silo

After all entries, modifications and results are checked and accepted, a report (pdf) can be created.

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

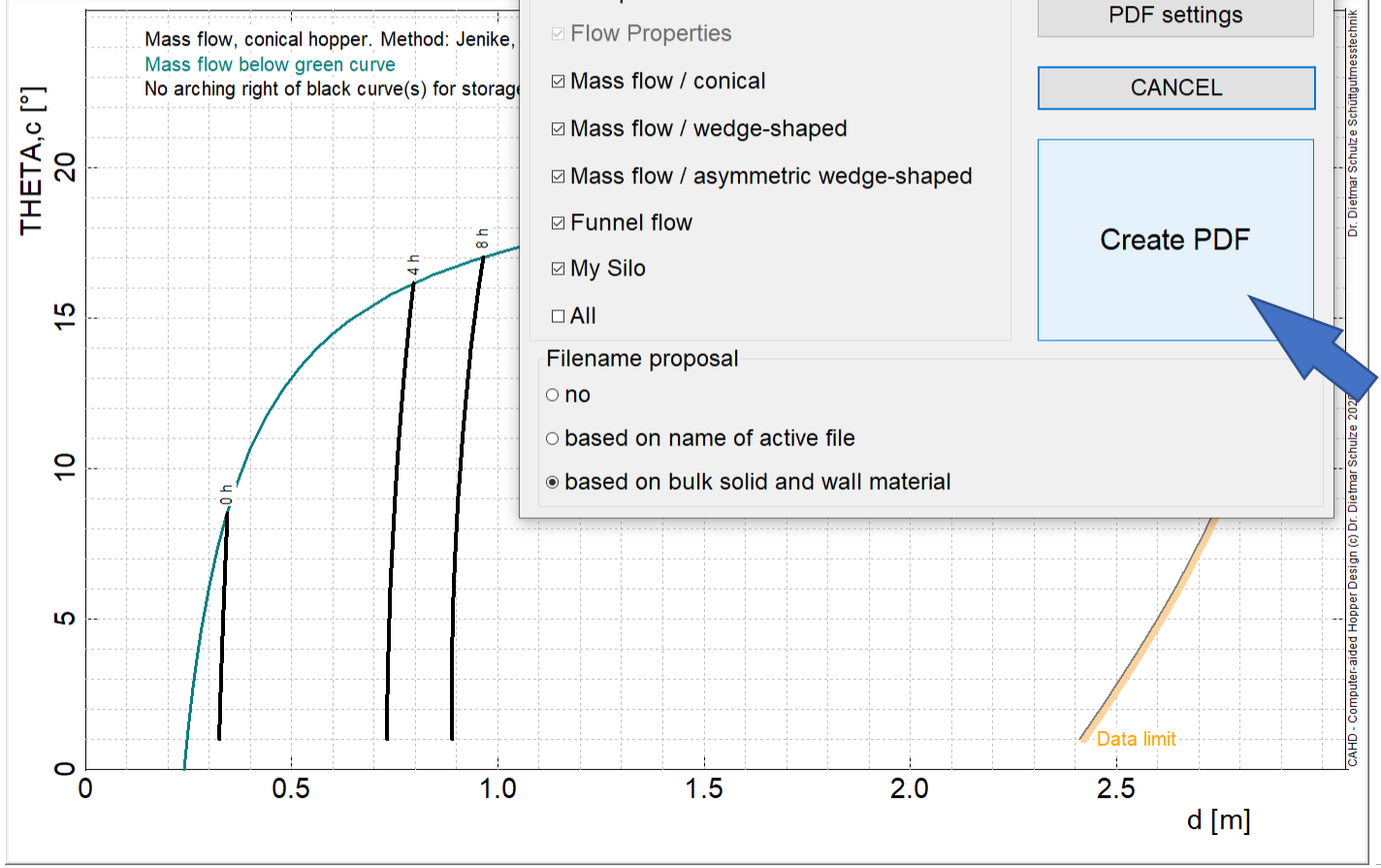
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Theta,c [°] | t [h]	0	4.00	8.00	Unit	Comment
19.0	1.848	1.848	1.848	m	Green: Minimum dimension for mass flow
18.0	1.253	1.253	1.253	m	Green: Minimum dimension for mass flow
17.0	0.954	0.954	0.964	m	Green: Minimum dimension for mass flow
16.0	0.768	0.794	0.953	m	Green: Minimum dimension for mass flow
15.0	0.646	0.786	0.944	m	Green: Minimum dimension for mass flow

Flow function | RHOB | PHIE | PHILIN | PHIX | WY



Printing...

Data to print

- [x] Flow Properties
- [x] Mass flow / conical
- [x] Mass flow / wedge-shaped
- [x] Mass flow / asymmetric wedge-shaped
- [x] Funnel flow
- [x] My Silo
- [ ] All

PDF settings

CANCEL

Create PDF

Filename proposal

- ( ) no
- ( ) based on name of active file
- (•) based on bulk solid and wall material

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile

- (•) Mass flow
- ( ) Funnel flow

Crit. values

- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8

- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

- [ ] My Silo

Selection of results to be included in the report

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

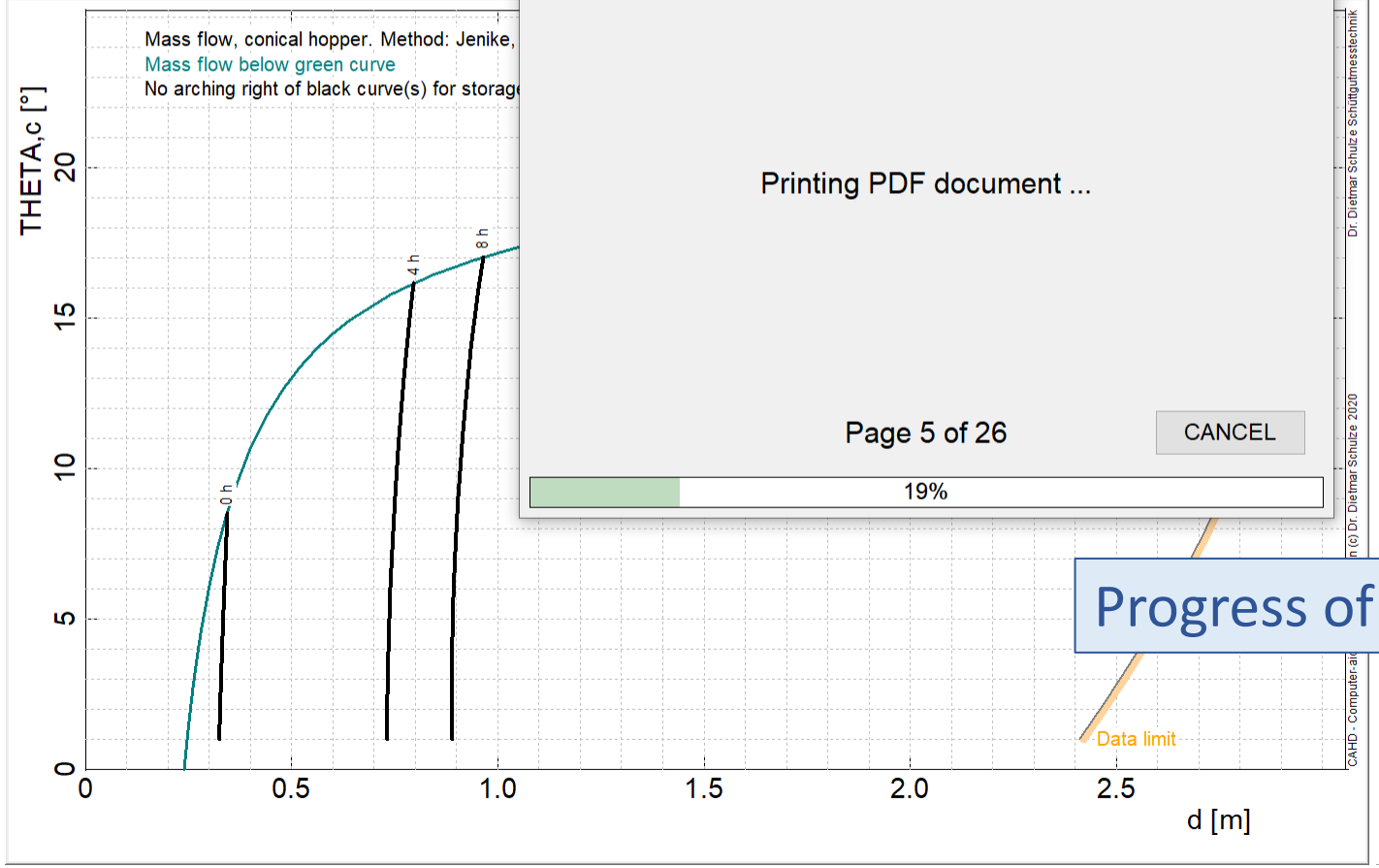
CREATE PDF

Yield loci | Wall friction | Time consolidation | MF: Cone | MF: Wedge | MF: As. wedge | FF: Rathole (LB) | FF: Rathole (UB) | FF: Arching (LB)

MF: Theta = f(b,d) | MF: d = f(Theta) | MF: b = f(Theta) | MF: b,as = f(Theta) | MF: d max | MF: b max | MF: b,as max | My Silo

Theta,c [°] | t [h]	0	4.00	8.00	Unit	Comment
19.0	1.848	1.848	1.848	m	Green: Minimum dimension for mass flow
18.0	1.253	1.253	1.253	m	Green: Minimum dimension for mass flow
17.0	0.954	0.954	0.964	m	Green: Minimum dimension for mass flow
16.0	0.768	0.794	0.953	m	Green: Minimum dimension for mass flow
15.0	0.646	0.786	0.944	m	Green: Minimum dimension for mass flow

Flow function | RHOB | PHIE | PHILIN | PHIX | W



Printing...

Printing PDF document ...

Page 5 of 26

CANCEL

19%

Hopper shape
- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

Flow profile
- (•) Mass flow
- ( ) Funnel flow

Crit. values
- (•) No (all)
- ( ) t = 0
- ( ) 4.00 h
- ( ) 8.00 h
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -
- ( ) -

□ My Silo

Progress of pdf printing process

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All | Change WYL | WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

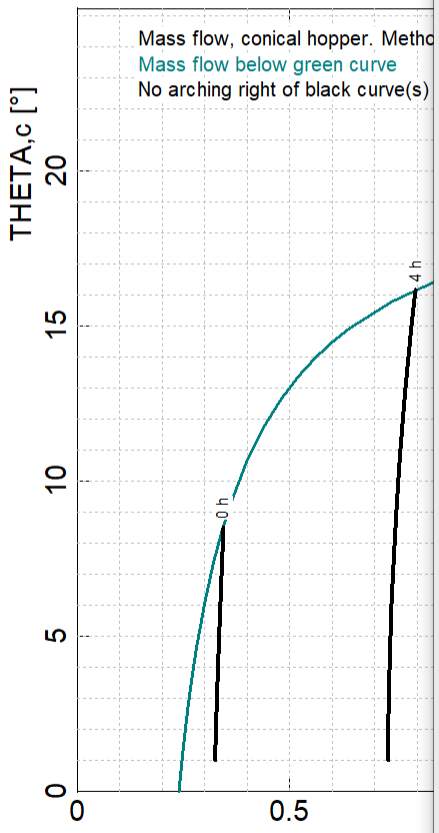
CREATE PDF

Yield loci | Wall friction | Tim

MF: Theta = f(b,d) | MF: d = f(

Theta,c [°] | t [h]	0	4.00
19.0	1.848	1.848
18.0	1.253	1.253
17.0	0.954	0.954
16.0	0.768	0.794
15.0	0.646	0.786

Flow function | RHOB | PHIE | PHILIN | P



Sample Powder_Mild steel St37.pdf - Adobe Acrobat Reader DC

Datei Bearbeiten Anzeige Unterschreiben Fenster Hilfe

Start Werkzeuge Sample Powder_Mil... ×

Anmelden

1 / 26 91%

CAHD v1.0.0.9 Computer-aided Hopper Design - Software by Dr. Dietmar Schulze 21.01.2021 16:26:46 page 1

File: C:\Users\Public\Documents\CAHDv1\Reports\Sample Powder_Mild steel St37.pdf

Silo Design for Flow

Bulk solid:

Sample Powder

Wall material:

Mild steel St37

Order:

XYZ Ltd.

Design created by: unknown

21.01.2021

Title page of report

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column

Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3

ff (MF) 1

My Silo (data input)

Theta [°] 20

b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

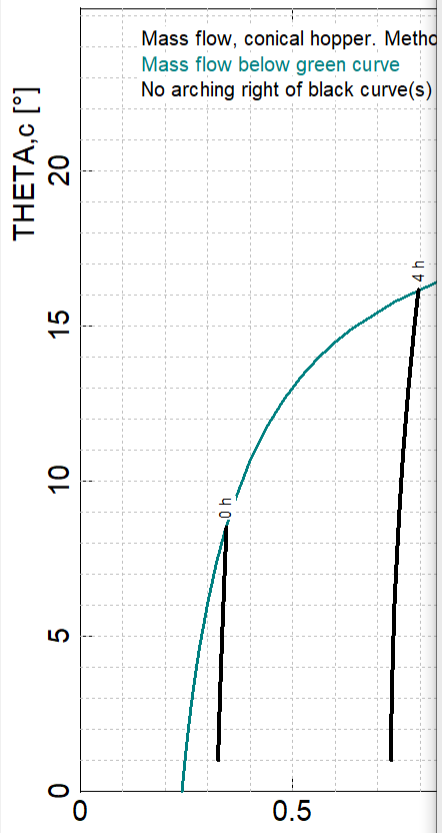
CREATE PDF

Yield loci | Wall friction | Tim

MF: Theta = f(b,d) | MF: d = f(

Theta,c [°] | t [h]	0	4.00
19.0	1.848	1.848
18.0	1.253	1.253
17.0	0.954	0.954
16.0	0.768	0.794
15.0	0.646	0.786

Flow function | RHOB | PHIE | PHILIN | P



Sample Powder_Mild steel St37.pdf - Adobe Acrobat Reader DC

Datei Bearbeiten Anzeige Unterschreiben Fenster Hilfe

Start Werkzeuge Sample Powder_Mil... ×

Anmelden

2 / 26 91%

CAHD v1.0.0.9 User: unknown 21.01.2021 16:26:46 page 2

Bulk solid: Sample Powder, Order: XYZ Ltd., Wall material: Mild steel St37

Flow properties for the design procedure

Test data: black
Data extrapolated by the program: purple
Extrapolated data, possibly modified by user: red
Data applied on design procedure, possibly modified by user: blue and "*"
The following functions are based on a user defined spline approximation:
RHOB

Flow properties derived from yield loci

SIGMA1 [Pa]	FC [Pa]	*FC [Pa]	RHOB [kg/m3]	*RHOB [kg/m3]	PHIE [°]	*PHIE [°]	PHILIN [°]	*PHILIN [°]
0	2523	1055	811	811	56.1	56.1	40.6	40.6
5417	2523	2523	1066	1066	51.2	51.2	38.6	38.6
9239	3671	3671	1114	1114	47.8	47.8	37.1	37.1
18315	6205	6205	1195	1195	45.7	45.7	36.8	36.8
20147	8037	7421	1211	1211	45.3	45.3	36.7	36.7

Wall friction (Mild steel St37)

SIGMA,w [Pa]	PHIX,min [°]	PHIX,m [°]	PHIX,max [°]	*PHIX [°]
10	87.9	88.0	88.0	88.0
955	34.7	34.9	35.1	34.9
9320	23.5	23.6	23.6	23.6
18613	23.0	23.1	23.3	23.1
27907	23.0	23.2	23.4	23.2
37200	22.8	22.9	23.0	22.9
46494	23.0	23.2	23.3	23.2
47423	23.1	23.2	23.3	23.2

Time consolidation:

	Storage time t [h]			
SIGMA1 [Pa]	4.00	*4.00	8.00	*8.00
0	3907	2374	4404	2990
5417	3907	3907	4404	4404
9239	5025	5025	5587	5587
18315				
20147	15932	9831	16495	12592

Important note - Disclaimer (Program CAHD):

The silo design results presented on the following pages are based on the above quantities printed in blue and red color.
This data may be incorrect, and/or may have been modified by the user.
For the calculations the design procedures selected by the user were applied. Alone the user is responsible
for the correctness of the silo design results. Thus, the user must be sufficiently educated in the silo design procedure.
Extrapolation, interpolation, and all calculations of the program have to be regarded as proposals which have to be reviewed critically
and may require modification by the user in order to obtain a reliable silo design.
Thus, the originator of this program does not take any responsibility for silo design results of this program.

The user shall accept and understand that no warranty and liability is expressed or implied by the originator of this program on the
accuracy and reliability of this program. Should the program prove defective, the originator shall bear no responsibility for all
resulting damages or losses.
By using this program, the user agrees to the terms above, and to the terms and conditions written in the manual of this program.

Flow properties and possible modifications by the user

Zur Suche Text hier eingeben

CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column | Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3 | ff (MF) 1

My Silo (data input)

Theta [°] 20 | b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

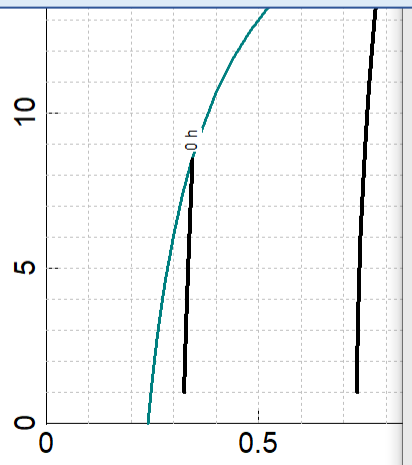
CALCULATE

CREATE PDF

Yield loci | Wall friction | Tim

MF: Theta = f(b,d) | MF: d = f(

Theta,c [°] | t [h]	0	4.00
19.0	1.848	1.848
18.0	1.253	1.253
17.0	0.954	0.954
16.0	0.768	0.794
15.0	0.646	0.786



Results for conical hopper:

- critical points for all storage times t
- d = f(Theta)
- Theta = f(d)

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Start Werkzeuge Sample Powder_Mil... Anmelden

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Bulk solid: Sample Powder, Order: XYZ Ltd., Wall material: Mild steel St37

Design of conical hopper (mass flow, arching)

Design method applied: Jenike
Safety margin for Theta,c: 3.0°. Safety factor for ff: 1.00; extended PHIE range (20°..80°)

Results based on interpolation between test data: black
Results based on extrapolation: red

Minimum outlet diameter to avoid arching, corresponding maximum hopper wall slope to obtain mass flow, and critical values of flow properties:

Time [h]	SIGMA1,cr [Pa]	SIGMAW,cr [Pa]	FC,cr [Pa]	RHOB,cr [kg/m3]	PHIE,cr [°]	PHIX,cr [°]	PHILIN,cr [°]
0	1803	1223	1544	975	54.4	32.4	39.9
4.00	4564	3576	3866	1056	52.0	25.8	38.9
8.00	5634	4469	4471	1069	51.0	25.1	38.5

Time [h]	Theta,c [°]	ff [-]	H [-]	d,cr [m]	q [-]	SIGMAV,cr [Pa]
0	8.5	1.172	2.13	0.344	0.145	608
4.00	16.2	1.244	2.25	0.796	0.155	1626
8.00	17.0	1.259	2.26	0.964	0.158	2033

Time [h]	Comment
0	
4.00	
8.00	

Hopper wall slope in dependence on local hopper diameter
Here you can find the maximum hopper wall slope against the vertical as a function of the local hopper diameter.
Important: This is NO statement on the minimum outlet diameter to avoid arching!

d [m]	Theta,c [°]	d [m]	Theta,c [°]	d [m]	Theta,c [°]	d [m]	Theta,c [°]	d [m]	Theta,c [°]
0.2398	0.0	0.4397	11.8	1.1400	17.7	2.1398	19.1	-	-
0.2498	1.4	0.4798	12.6	1.2410	17.9	2.2405	19.2	-	-
0.2598	2.6	0.5213	13.4	1.3404	18.2	2.3402	19.2	-	-
0.2698	3.6	0.5603	14.0	1.4401	18.4	2.4401	19.3	-	-
0.2798	4.6	0.6014	14.5	1.5399	18.6	2.5399	19.3	-	-
0.2997	6.1	0.6401	14.9	1.6405	18.7	2.6406	19.4	-	-
0.3197	7.3	0.7399	15.8	1.7400	18.9	2.7398	19.4	-	-
0.3397	8.4	0.8405	16.4	1.8411	19.0	2.8405	19.4	-	-
0.3597	9.2	0.9402	16.9	1.9406	19.0	-	-	-	-
0.3997	10.7	1.0397	17.3	2.0410	19.1	-	-	-	-

Minimum outlet diameter to avoid arching in dependence on hopper wall slope and storage time at rest
Here you can find the minimum outlet diameter d to avoid arching for the measured storage times as a function of hopper wall slope Theta.
Green dimensions result from mass flow boundary.

	Storage time t [h]			
Theta,c [°]	0	4.00	8.00	Unit
19.0	1.848	1.848	1.848	m
18.0	1.253	1.253	1.253	m
17.0	0.954	0.954	0.964	m
16.0	0.768	0.794	0.953	m
15.0	0.646	0.786	0.944	m
14.0	0.560	0.779	0.934	m
13.0	0.497	0.772	0.927	m
12.0	0.449	0.766	0.921	m
11.0	0.410	0.760	0.914	m
10.0	0.379	0.755	0.909	m
9.0	0.354	0.751	0.903	m
8.0	0.343	0.747	0.900	m
7.0	0.340	0.743	0.896	m
6.0	0.337	0.739	0.893	m
5.0	0.334	0.737	0.891	m
4.0	0.331	0.735	0.889	m
3.0	0.329	0.733	0.888	m
2.0	0.326	0.731	0.888	m
1.0	0.324	0.731	0.889	m

Zur Suche Text hier eingeben

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Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column

Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3

ff (MF) 1

My Silo (data input)

Theta [°] 20

b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
- ( ) Asym. wedge

More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Tim

MF: Theta = f(b,d) | MF: d = f(

Theta,c [°] | t [h]	0	4.00
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17.0	0.954	0.954
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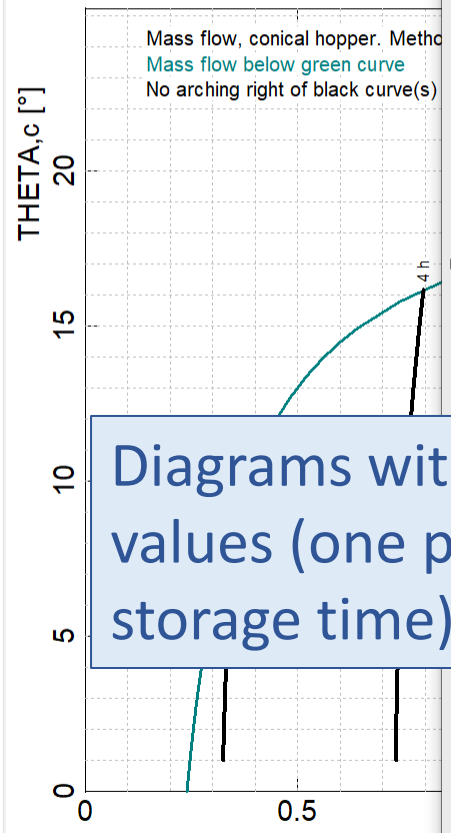
Flow function | RHOB | PHIE | PHILIN | P



Diagrams with critical values (one page per storage time)

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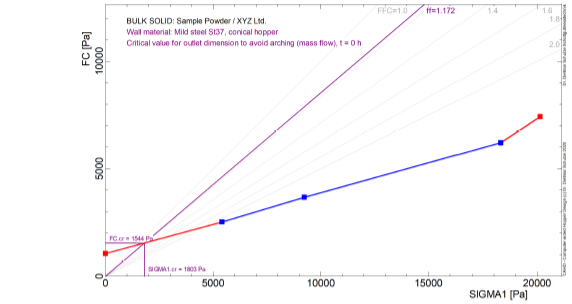
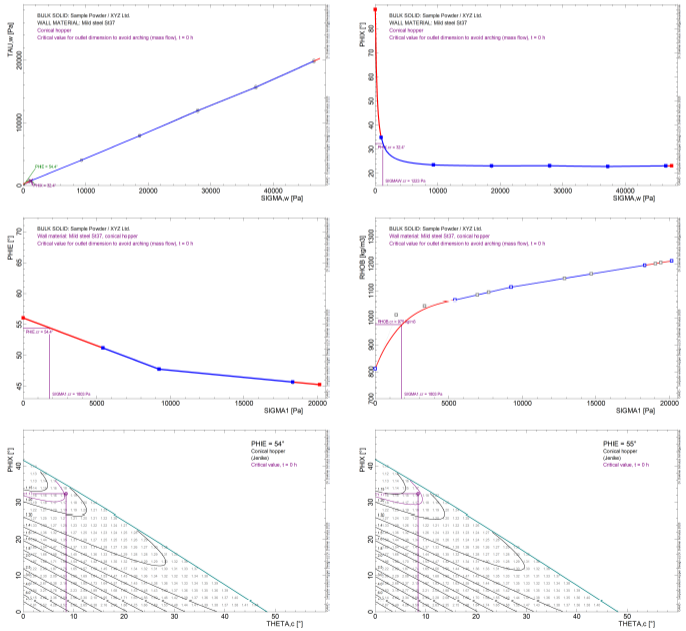
Bulk solid: Sample Powder, Order: XYZ Ltd., Wall material: Mild steel St37

Hopper design diagrams: Conical hopper, Storage time 0 h, Mass flow





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CAHD

File Test data Actual diagram Actual Table Tools Preferences Admin Help Log in

Yield loci | Time yield loci | Wall yield loci | Hopper Design

Edit flow properties

Edit cell

Reset:

Cell | Column

Table | All

Change WYL

WYL Reg | WYL SS

Safety for

Theta,c [°] 3

ff (MF) 1

My Silo (data input)

Theta [°] 20

b, d [m] 0.5

Hopper shape

- (•) Cone
- ( ) Wedge
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More settings

CALCULATE

CREATE PDF

Yield loci | Wall friction | Tim

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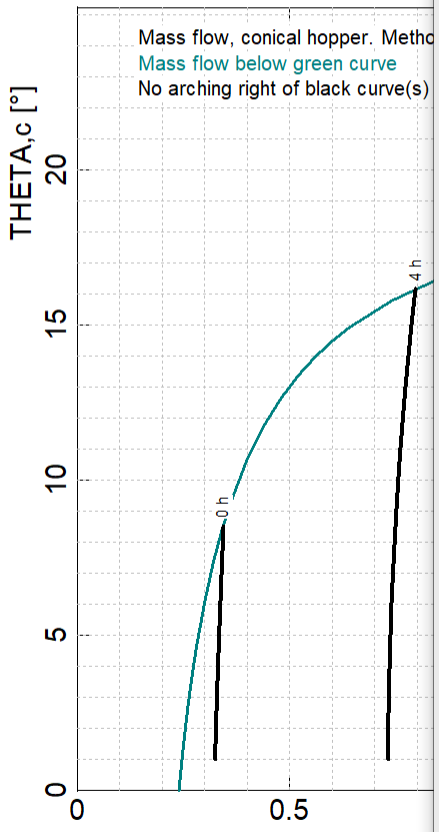
Flow function | RHOB | PHIE | PHILIN | P



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Start Werkzeuge Sample Powder_Mil... Anmelden

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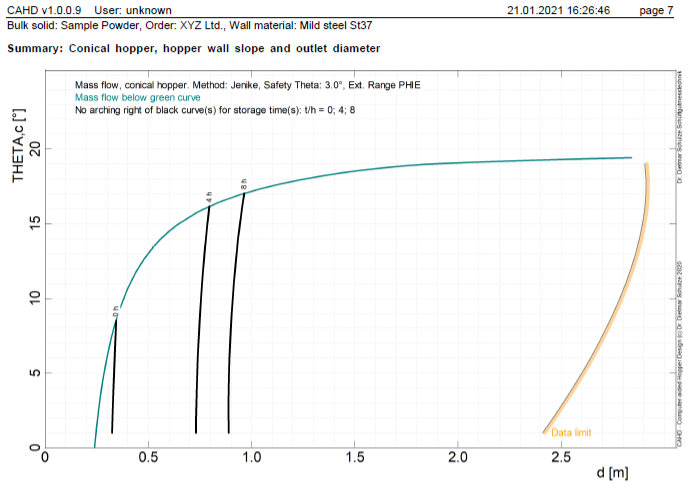

Theta-d-diagram

More diagrams are included for wedge-shaped hoppers, asymmetric wedge-shaped hoppers, “My silo” , maximum outlet dimensions (in case of a second intersection of flow function with ff-line), arching and ratholing in case of funnel flow (upper bound, lower bound).

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Thank you for your kind attention.