

Sublimation

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Volunteer for PDA

Overview

- Theory of Sublimation
- Practical aspects of Suplimation
- PAT
- Recipe & Transfer Parameters
- Hands-On: Barometric / Manometric Temperature Measurement

Theory of Sublimation

General Equation for Heat Transfer

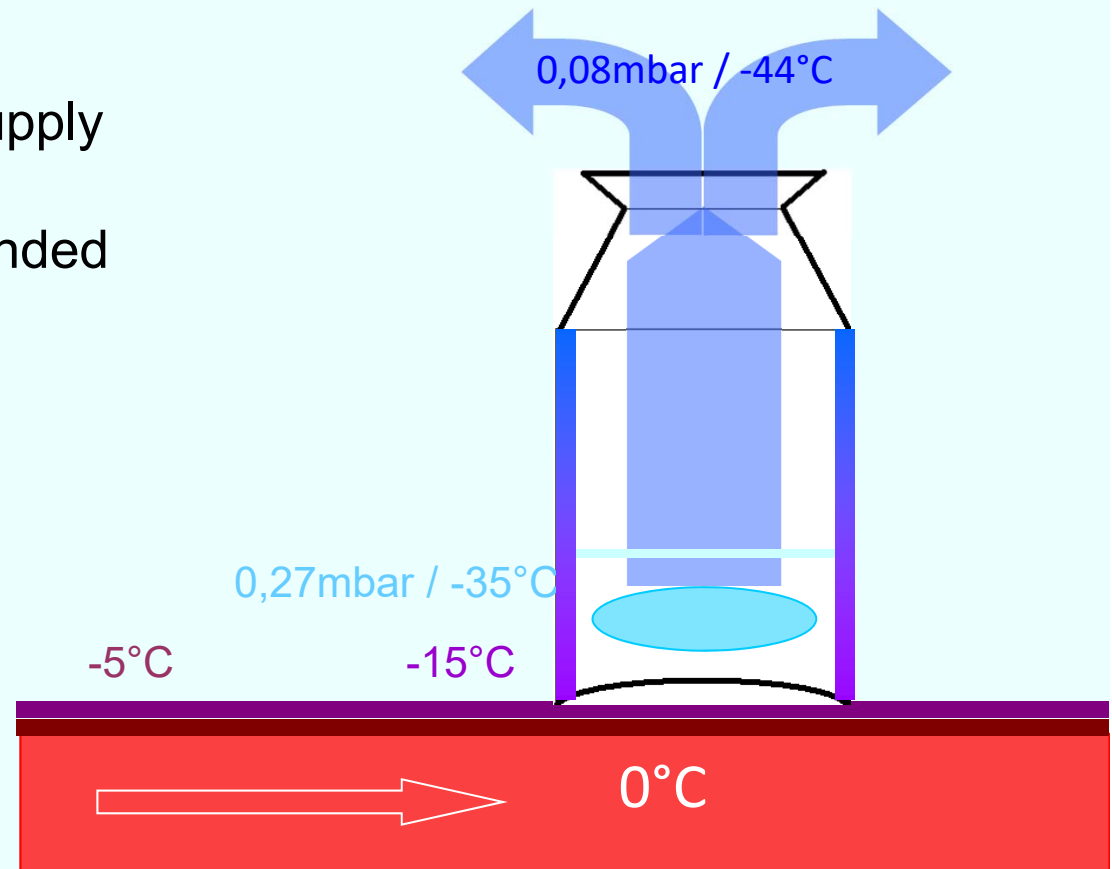
$$dQ_{Cond} + dQ_{Rad} + dQ_{Conv} = dQ_{comp}$$

$$\frac{dQ_{comp}}{dt} = k_V \cdot A_H \cdot [T_{Siliconeoil} - T_{Product}]$$

k_V	Very simplified Heat Transfer Coefficient
A_H	Vial Bottom Area
$T_{Product}$	Product at the Sublimation front

Sublimation – Thermic & Pressure profile

- Frozen water evaporates
- Process requires high energy supply
- Steady conditions are recommended

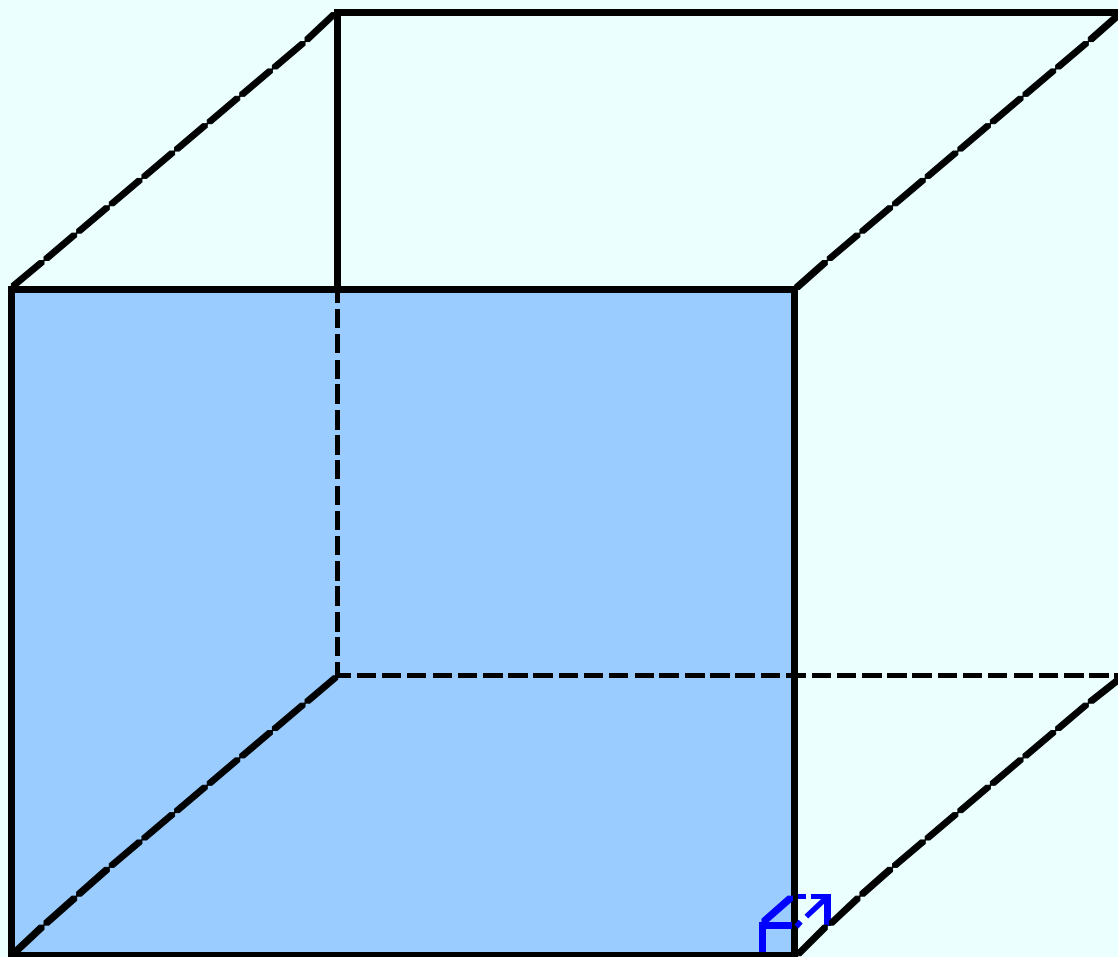


Heat Flux is stationary

- Each step of energy transfer transfers same amount of energy
- Temperature difference and thermal resistance are proportional
- Temperature gradient in vial is changing during sublimation

$$\frac{1}{K_v} = \sum_i \left[\frac{1}{K_i} \right] \Leftrightarrow K_v = \frac{1}{\sum_i \left[\frac{1}{K_i} \right]}$$

Partial Heat Transfer	Coefficient [W / m ² K]
Silicone Oil => Shelf Surface	40...250
Shelf Surface => Vial Bottom	8...20
Vial Bottom => Sublimation Front	100...1000



Comparison of liquid and gaseous volume of same mass

Gas production due to sublimation

- Sublimation provides tremendous gas volume
- e.g. 1 kg of ice sublimates into 13.220m³ (-44°C / 8Pa)

General Equation for Mass and Heat balance of the vial

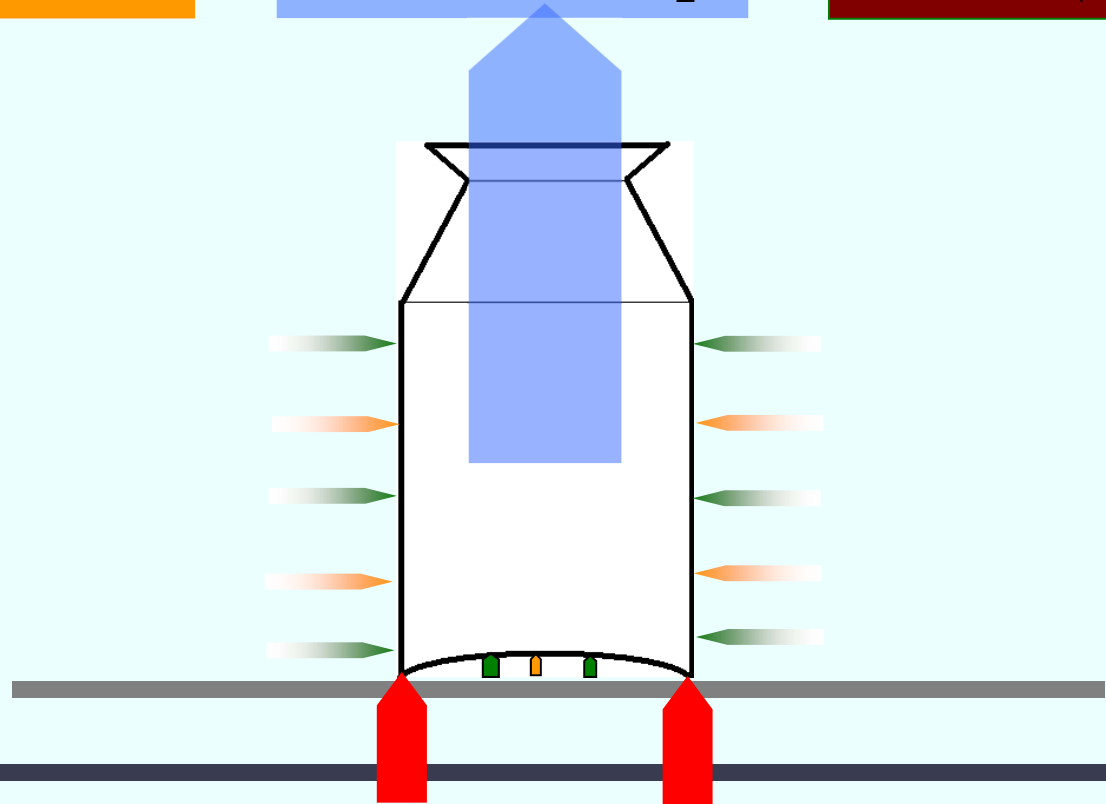
$$dQ_{Cond} + dQ_{Rad} + dQ_{Conv} = h_{Subl} \cdot dm_{H_2O} + d\vartheta \cdot C_{(\vartheta)}$$

Heat conduction

Heat radiation

Heat convection

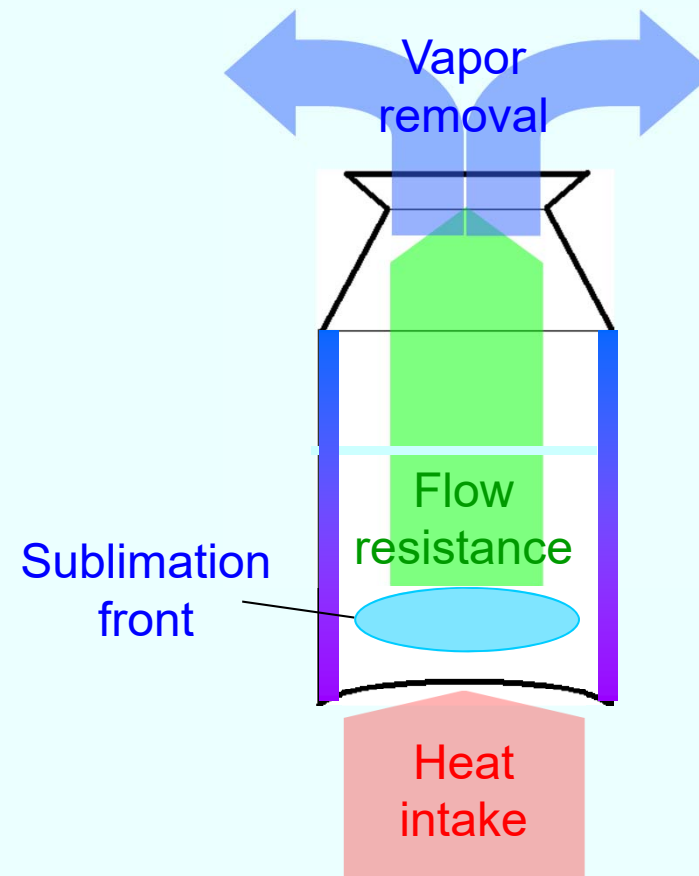
Sublimation



Sublimation at the front

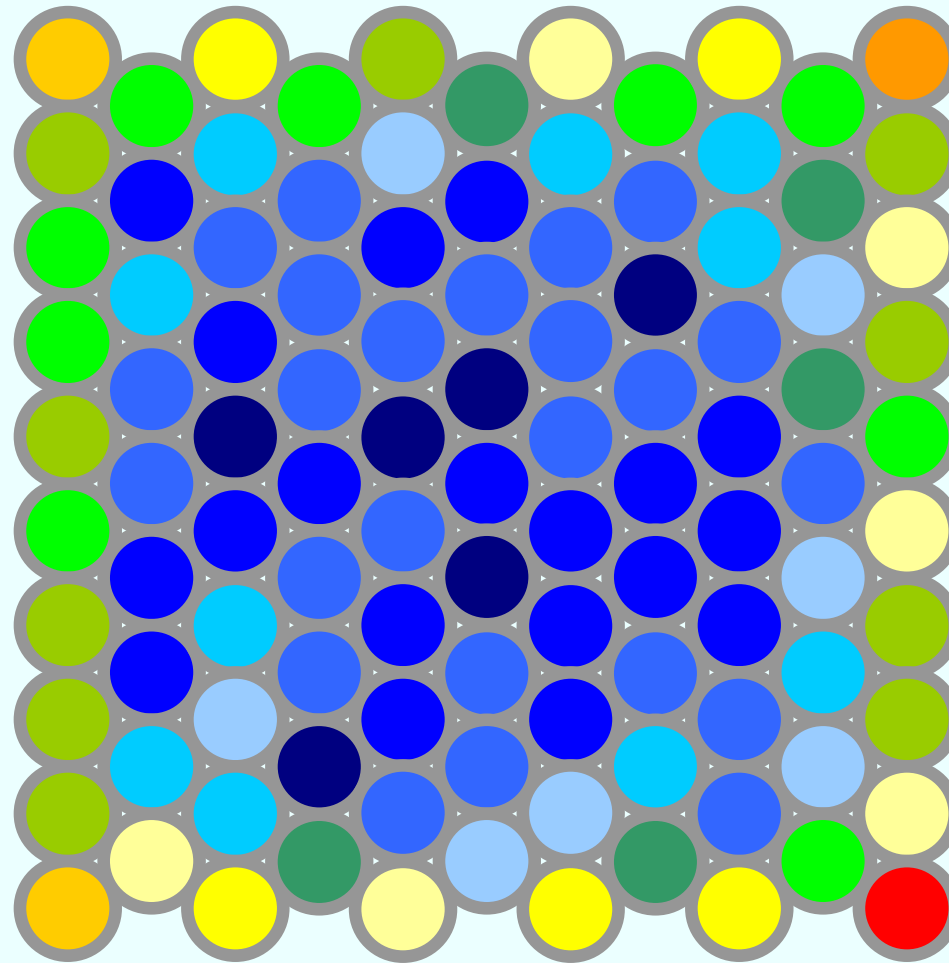
- Heat intake equilibrates with heat consumption by ice sublimation
- Driving force for mass flow is pressure difference
- Driving force for heat flux is temperature difference

$$\frac{dm}{dt} = \frac{A_P}{R_{PS}} \cdot (P_i - P_C) = \frac{dQ_{\text{subl}}}{h_{\text{subl}}}$$



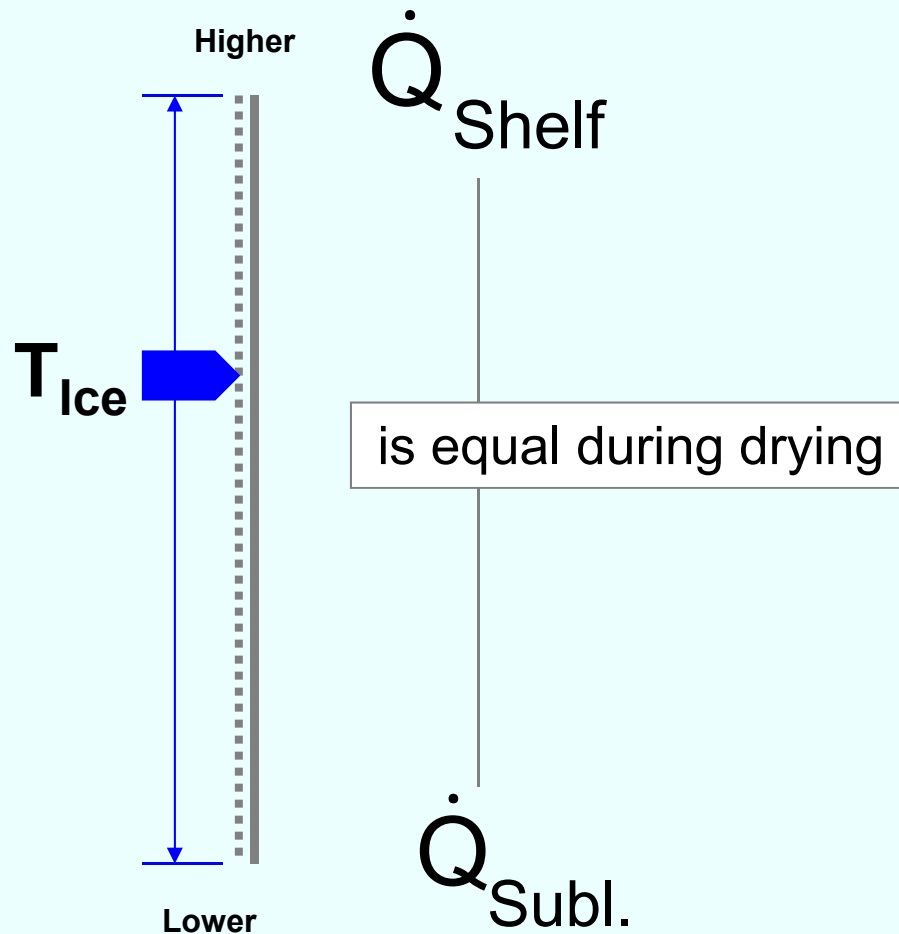
Impact of different Heat intake on Homogeneity

Vialtype: 10ml Vial
 Filling: 5ml
 Layer: 8mm
 T_{Sh} : 0°C
 T_{Rad} : 0°C
 p_{ch} : 80µbar
 t_{End} : 8h
 m_{min} : 1,88g; 0,24g/h
 m_{max} : 3,64g; 0,45g/h
 Base: 3 runs aver.



	min	max
	1,85g	1,98g
	1,98g	2,10g
	2,10g	2,23g
	2,23g	2,35g
	2,35g	2,48g
	2,48g	2,60g
	2,60g	2,73g
	2,73g	2,85g
	2,85g	2,98g
	2,98g	3,10g
	3,10g	3,23g
	3,23g	3,35g
	3,35g	3,48g
	3,48g	5,00g

Equilibrium of T_{Ice}



Limitations of Heat supply

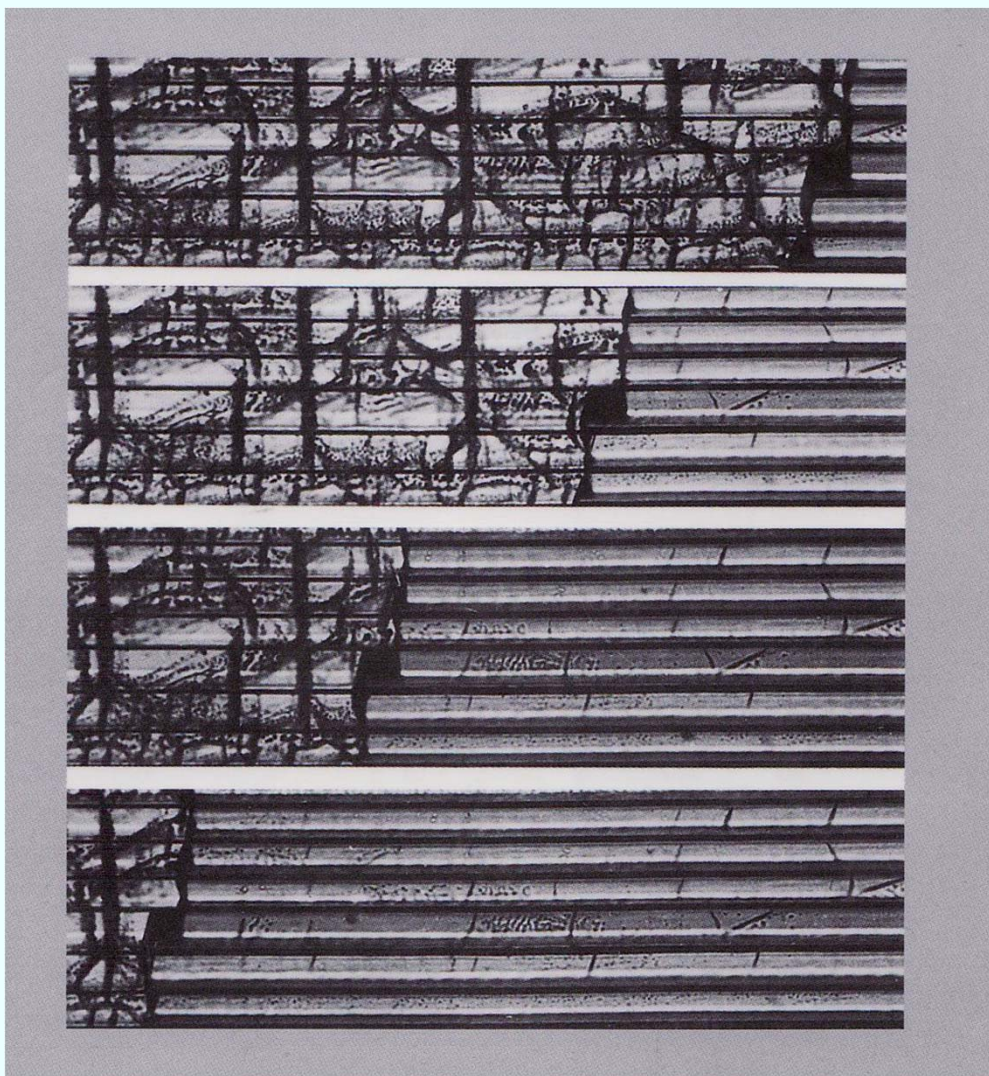
- Heat transfer coefficient in the shelf
- Heat transfer coefficient between shelf surface and sublimation front
- Difference between T_{Ice} and $T_{Silicone\ oil}$

Limitations of Sublimation Rate

- Cooling capacity of ice condenser
- Flow resistance of Freeze Dryer
- Vapor transport in product

Sublimation progress

- 90s
- 180s
- 270s
- 360s



Course of Freeze Drying at FD-Microscope (Bookcover, Oetjen/Haseley)

At the end of sublimation all
ice is removed

Questions?

Practical Aspects of Sublimation

Sublimation phase – Hints for a first run (I)

When process vacuum is reached the shelves should be heated up...
...Sublimation starts

- As shown before, the temperature at the sublimation front (T_{ice}) depends on the equilibrium of shelf temperature and chamber vacuum
- T_{ice} must never exceed the critical temperature investigated with one of the previously described instruments
- A proper process vacuum could be the vapor pressure of ($T_{crit} - 5...10^{\circ}C$)

Sublimation phase – Hints for a first run (II)

When process vacuum is reached the shelves should be heated up...
...Sublimation starts

- A first estimation for step duration could be calculated based on sublimation progress of $0,5\text{mm}_{\text{Layer}}/\text{hour}$
- Due to variations in Drying Progress over time, changes in Shelf Temperature or Process Vacuum during Sublimation should be avoided
- For a first guess, a conservative Temperature difference between t_{crit} and t_{shelf} of 15°C can be assumed

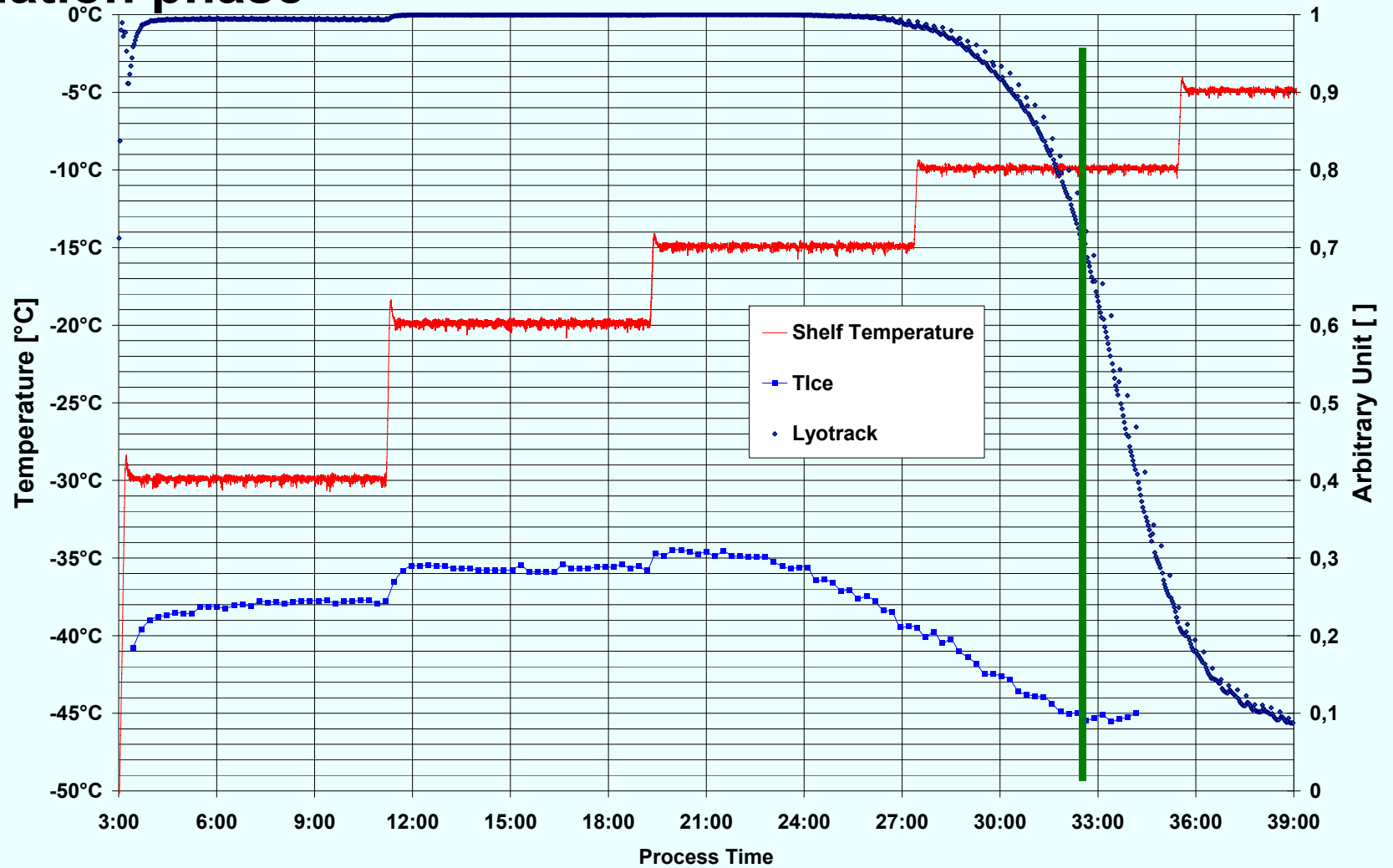
Optimization of Sublimation phase (I)

- Every raise of T_{ice} by $+1^{\circ}\text{C}$ increases process speed by 10...15%
- Frequently performed Pressure Rise Analysis enable safe monitoring of right T_{ice}
- The average T_{ice} can be also calculated based on TDLAS results

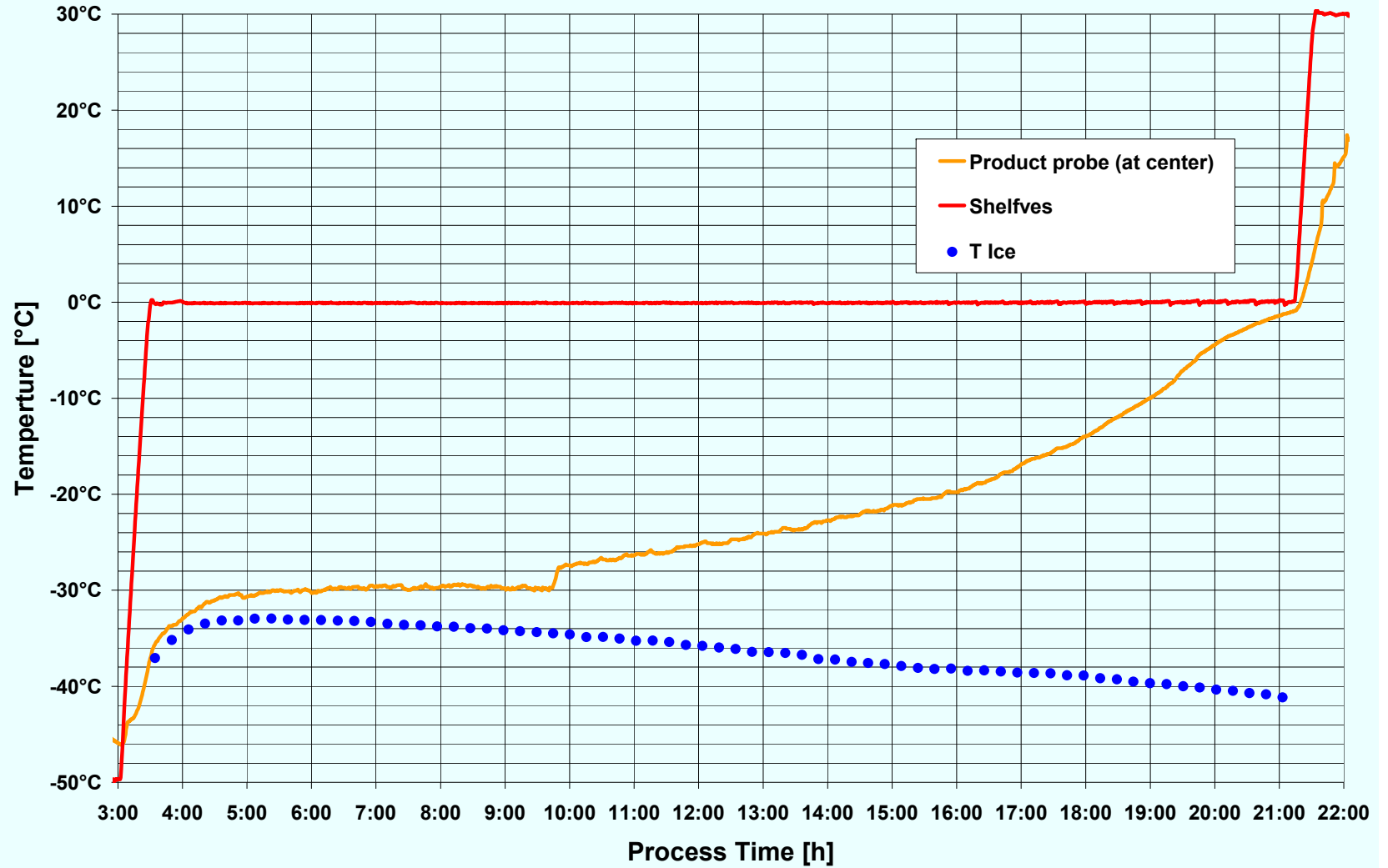
Optimization of Sublimation phase (II)

- The use of PAT Tools allows the safe control of the right step time
- The ice is safely removed, when
 1. the Temperature probes are above the shelf temperature (*requires time margin and right positioning of the temperature sensors*)
 2. T_{ice} has reached the equivalent vapor temperature of the chamber vacuum
 3. the Pirani Vacuum converges to the capacitive vacuum closer than 5%
 4. the indicated Lyotrack value has reduced below 0,4
 5. the Sublimation Rate has reduced to some percents of its maximum value

Sublimation phase



Sublimation phase



Temperature Measurement during Sublimation phase

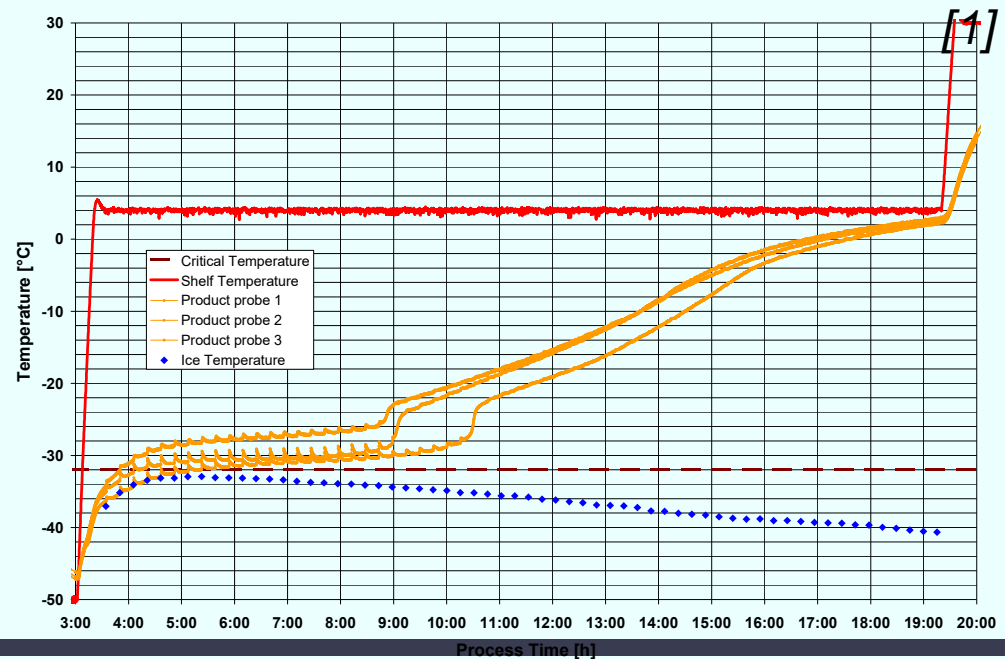
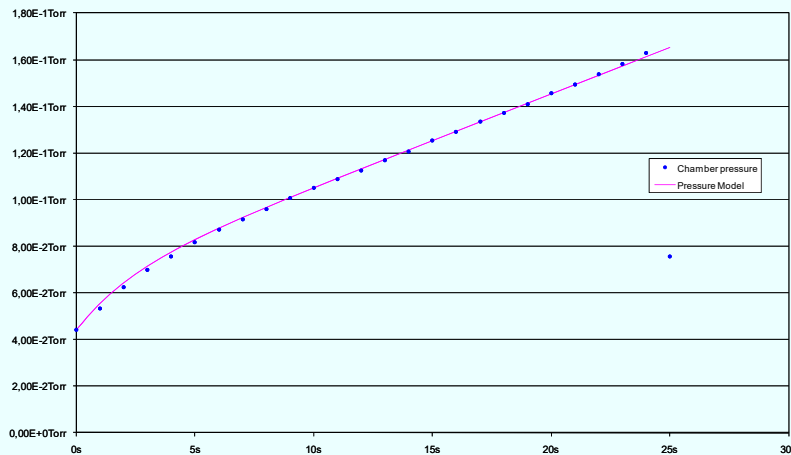
Procedure	Temp. Probes	Manometric / Barometric Temperature measurement	Temperature Calculation by TDLAS
Aseptic Handling	If wireless	yes	yes
Process impact	no	Yes	no
Main Valve close time	No process impact, always open	3...25s	No process impact, always open
Measuring scope	Indefinable position at vial	Full load	Full load
Other Considerations	Monitoring of some Samples only, Comparability of Samples with Cycle	Detects always the most critical vials in the process	Calculates the general average of t_{ice}

PAT

PAT @ Sublimation:

Process Feedback for Sublimation

- Ice Temperature (Frozen Product / sublimation Front)
 - Conventional Sensors (PT100 / TC / Wireless)
 - Barometric / Manometric Temperature Detection
 - Analysis of TDLAS results



PAT @ Sublimation:

Process Feedback for Sublimation

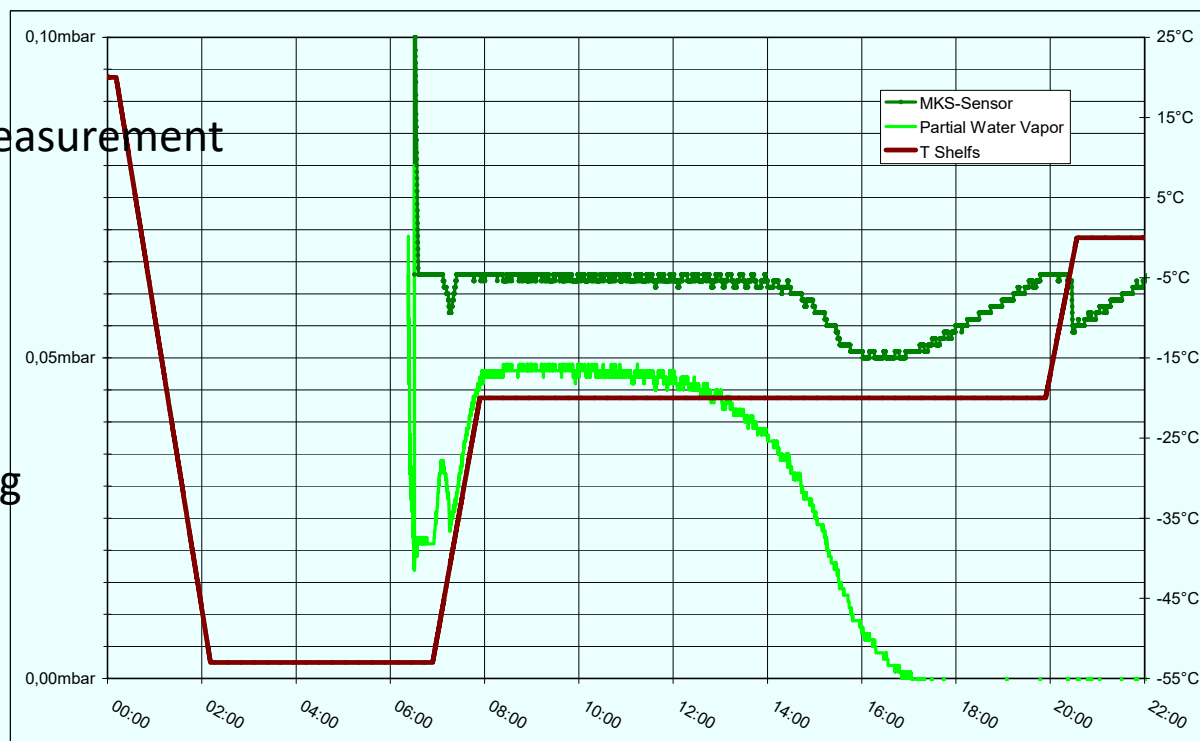
- Vapor Flow into Condensor
 - TDLAS
 - Analysis of Pressure Rise Measurement e.g. the frequent measurement of Sublimation / Evaporation Rate

$$ER = \frac{\Delta p / [\mu\text{bar}]}{\Delta t / [\text{s}]} \cdot \frac{V_c / [\text{m}^3]}{v_s / [\text{K}]} \cdot \frac{1}{m_{Tr} / [\text{kg}]} \cdot 0,7803 = \left[\frac{1}{\text{h}} \right]$$

PAT @ Sublimation:

Further Process Feedback for Sublimation

- Vapor Concentration
 - Comparative Pressure Measurement
 - Cold Plasma
 - NIR Gas Analysis
 - MS Gas Analysis
 - Dew Point Detection
 - Inert Gas Flow Monitoring



PAT @ Sublimation:

Process Feedback for Sublimation

- Ice Loss of Load
 - (Micro) Balance at Product Area
 - Sample Thief with Balance
- Ice Increase at Condenser
 - Weighing Function at the Ice Condenser
 - Thickness indication of Ice Layer
- Structural change of Product (Nucleation Sensors)

Recipe & Transfer Parameters

Investigation of the sublimation process

- A freeze Drying Microscope allows a detailed analysis of the drying process and a proper assessment for the suitability of the porosity of the frozen structure.
- The Correlation of the Evaporation Rate with the Water/Ice content allows a safe prediction of the End of Primary Drying
- The profile of T_{ice} vs. Progress can be considered as transfer Parameter. As long this profile is likewise at different Lyos, the processes can be considered as comparable.

Principles for Sublimation

<i>Procedure</i>	<i>Principle</i>	<i>Result</i>
BTM / MTM product parameter	Indirect calculation of T_{ice} by Pressure Rise Analysis	Direct control of temperature at sublimation front
Gas Flow process parameter	Indirect calculation of sublimation rate by detecting vapor velocity	Determination of end point of sublimation phase
Gas Moisture process parameter	Direct measurement of partial vapor concentration	Determination of end point of sublimation phase

Some Questions of mine :

- ✓ meaning of K_v ?
- ✓ Volume per kg Ice (80µbar, -44°C)?
- ✓ Increase of process speed by raise of $T_{ice} +1°C$?
- ✓ Difference between T_{shelf} & T_{ice} ?
- ✓ Difference between T_{shelf} & $T_{silicone\ oil}$?
- ✓ „Comparative Pressure measurement“?
- ✓ Indicators for end point of sublimation?

Hands-on: Barometric / Manometric Temperature Measurement

Theory of Barometric Temperature Measurement (BTM)

Pressure profile is driving force of lyophilization

Pressure at sublimation front,
not directly measureable

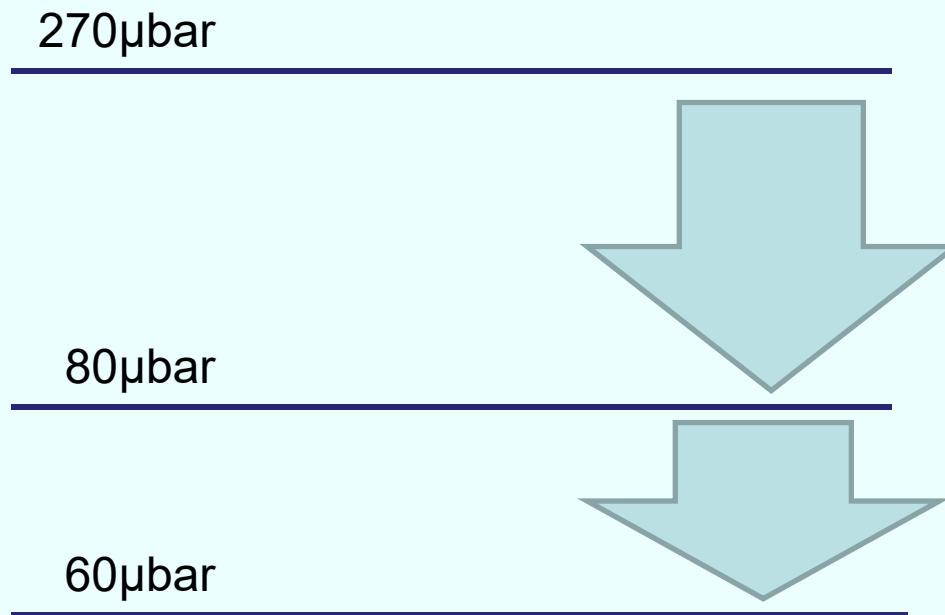
270 μ bar

Chamber pressure,
directly measureable

80 μ bar

Condenser pressure,
directly measureable

60 μ bar



Theory of Barometric Temperature Measurement (BTM)

- Indirect measurement of pressure at sublimation front by closing the intermediate valve

ZEICHNUNGEN BLATT 1

AUSGABETAG: 26. FEBRUAR 1969

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KL. 82 a 1/01

INTERNAT. KL. **F 26b**

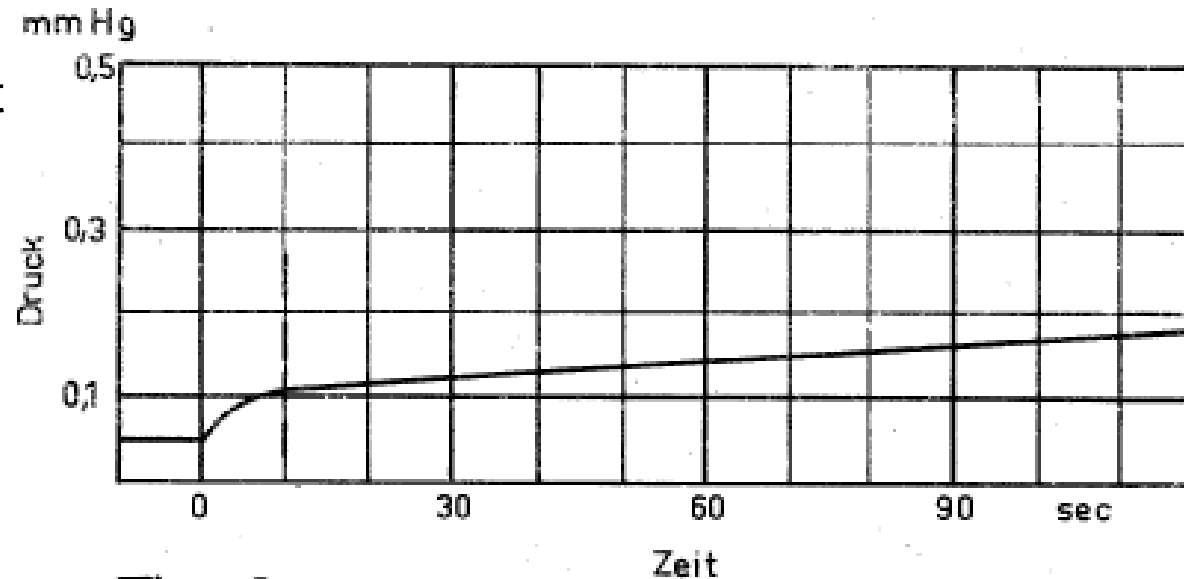


Fig. 2

Theory of Barometric / Manometric Temperature Measurement (BTM / MTM)

- Pressure equalizes at equilibrium point
- Further pressure rise is result of steady warming of the whole batch => Risk of product melt
- Equilibrium point and pressure rise characteristic changes with sublimation progress

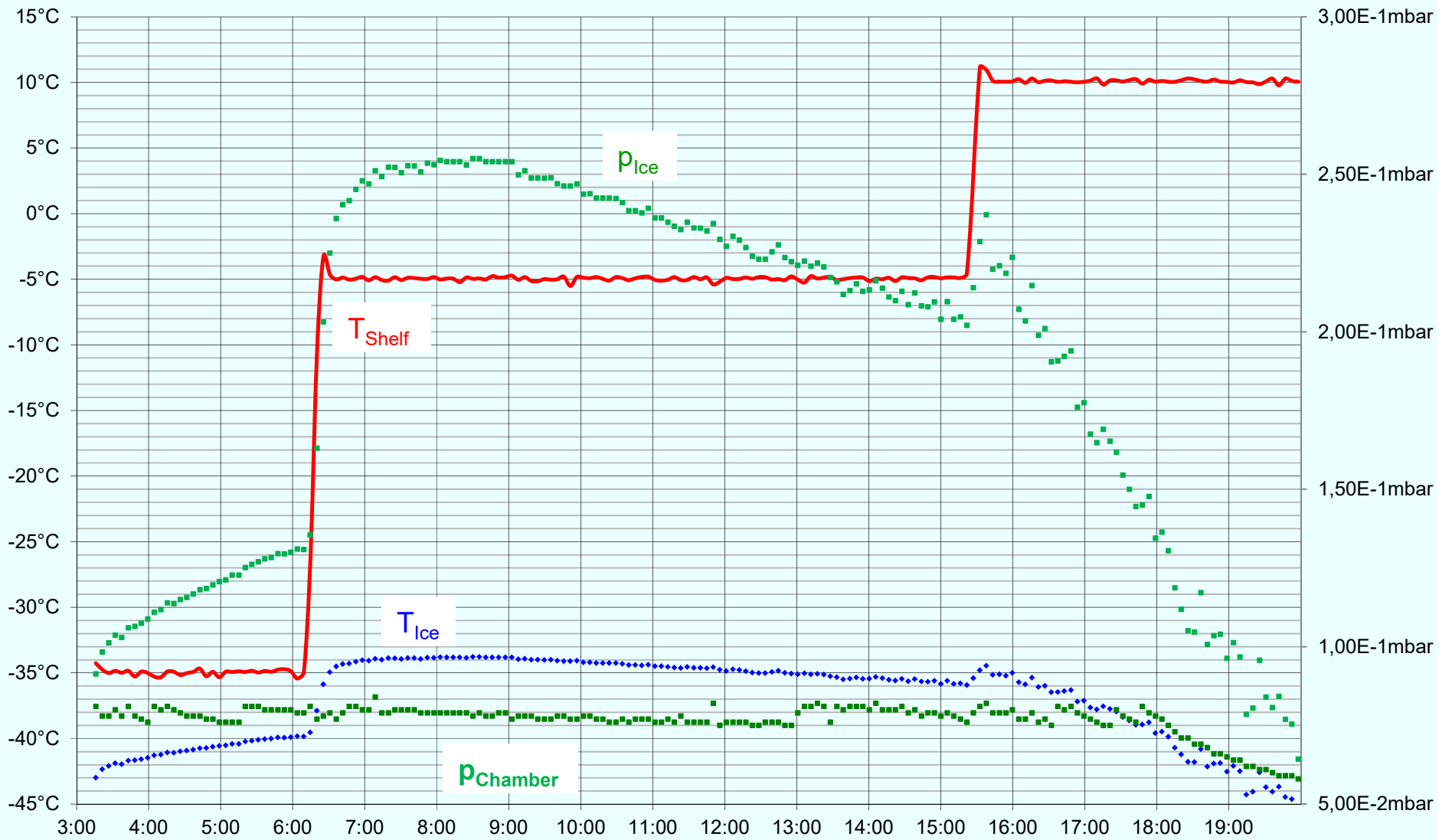
Theory of Barometric Temperature Measurement (BTM)

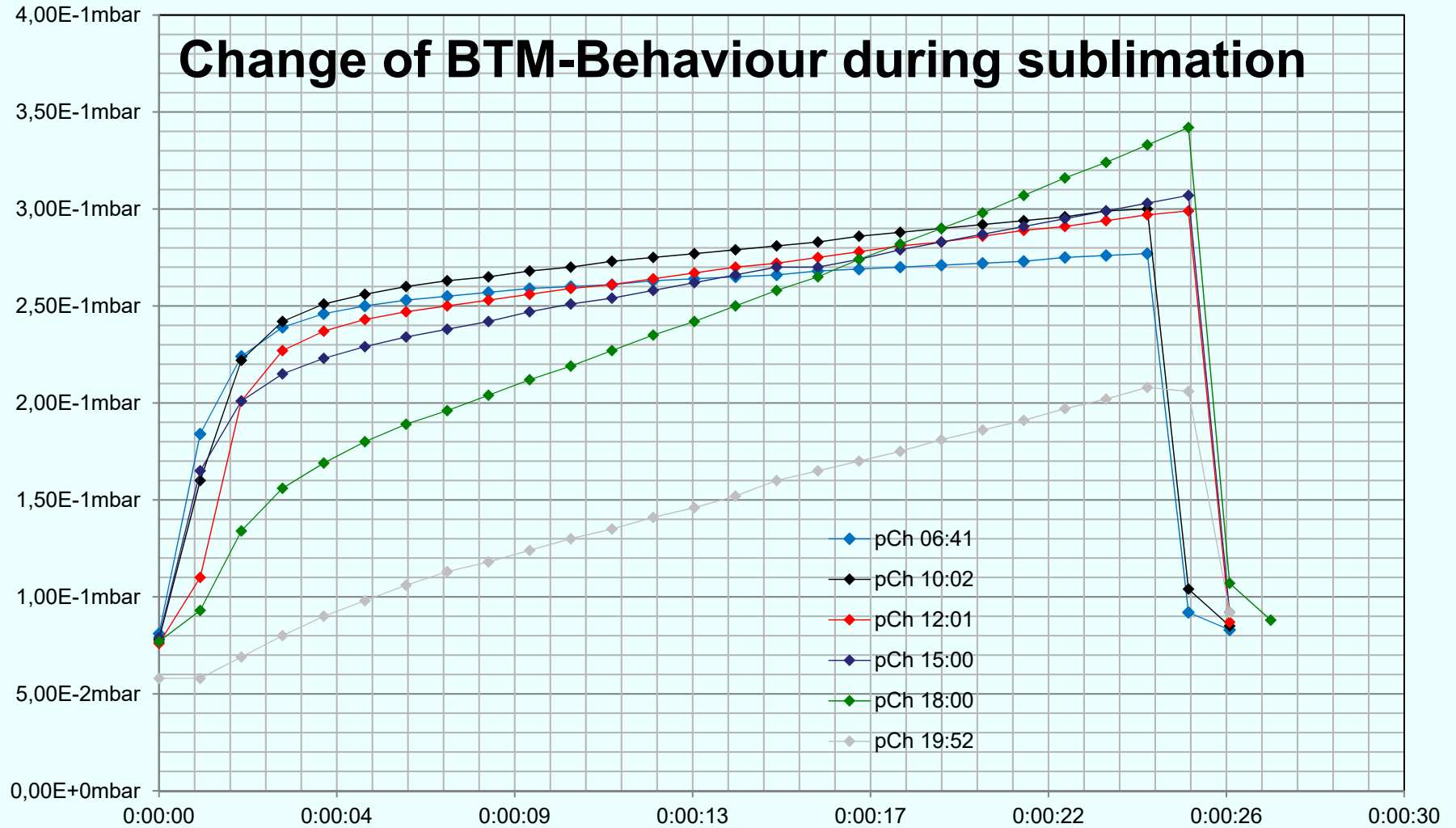
- Procedure is sensitive against low number of remaining vials
- A change of shelf temperature for cycle tuning is not recommendable => process inhomogeneity
- The numeric fit-procedure allows the calculation of the results with MS-Excel

Theory of Barometric Temperature Measurement (BTM)

$$P_{(t)} = P_{ice} - (P_{ice} - P_0) \cdot e^{-t \cdot \frac{N \cdot A_p \cdot 62,3 \cdot T'}{18 \cdot V \cdot R_p \cdot 3600}} + 0,0465 \cdot P_{ice} \cdot \left(\frac{24,7 \cdot L_{ice} \cdot (P_{ice} - P_0)}{R_p} - 0,0102 \cdot L_{ice} \cdot \frac{\left(T' - \frac{6144,96}{24,01849 - \ln(P_{ice})} \right)}{1 - 0,0102 \cdot L_{ice}} \right) \cdot \left(1 - 0,811 \cdot e^{\left(-0,114 \cdot \frac{t}{L_{ice}} \right)} \right) + EX \cdot t$$

Symbol	Unit	Description	
$P_{(t)}$	[Torr]	Chamber pressure	Measured
P_{ice}	[Torr]	Vapor pressure at sublimation front	To be solved
P_0	[Torr]	Chamber pressure at start of BTM	Measured
N	[]	Number of vials	To be known
A_p	[cm ²]	Average surface of the vial	To be known
T'	[K]	Shelf temperature	Measured
V	[l]	Effective chamber Volume	To be known
R_p		Flow resistance of dried cake	To be solved
L_{ice}	[cm]	Filling level, Layer thickness	To be known
EX		Linear part of pressure rise due to leak rate and warming of product	To be solved
t	[s]	Time	Measured





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Thank you for your attention!

Questions?

Table of critical temperatures

Sucrose	amorphous	307,9μbar	-32°C
Mannitol	crystalline	3.685,0μbar	-6°C
Lactose	amorphous	466,9μbar	-28°C
NaCl	crystalline	850,2μbar	-22°C
CaCl₂	crystalline	23,8μbar	-54°C

Preparation to use the Excel-Solver

- Activate Macros / Deactivate “protection”
- Register Solver in MS-Excel
- Install Solver as VBA-Reference

The screenshot shows the Microsoft Excel interface for the file 'BTM-Calculator Berlin.xlsm'. A yellow security warning bar is visible at the top, stating 'Sicherheitswarnung Makros wurden deaktiviert. Inhalt aktivieren'. The spreadsheet contains various parameters and calculated values for a BTM calculator. The formula bar shows the formula for cell F8: $=6145/(24,305-LN(Pice))-K3$.

Row	Column	Value / Formula
1	F	Fit
2	P ₀	8,1E-2mbar
2	P _{Ice}	2,5E-1mbar
2	G	1,8E-1Torr
2	K	1,333mbar/Torr
3	T _{shelf}	0,0°C
3	C	273,2K
3	K1	3,5E-1[1/K s]
3	K	273,15
4	N	210 Vials
4	K2	1,3E-3mbar/s
5	D _{Vial}	28 mm
5	C	2,8cm
6	Vial thickness	1 mm
6	C	0,1cm
6	RMS	11,70
7	A _p	5,31cm ²
8	V _{chamber}	66 l
8	C	6,60E-2m ³
8	T _{Ice}	-34,1°C
9	Filling height	8 mm
9	C	0,8cm
9	T _{shelf}	0,0°C
11	R _p	2,87E+1cm ² mbar h/g
11	Leak rate	5,00E-3 mbar x l / s
12	EX	1,3E-3mbar/s
12	K	7,6E-5mbar/s
12	L	5,7E-5Torr/s
12	K	1,8E-3mbar
14	Filling	3,0g
15	Concentration	5%
16	Solid Content	31,5g
16	C	3,15E-2kg
18	Pressure Rise	2,0E-1mbar
18	C	2,0E+2μbar
19	Δt	24,0s
20	ER	4,9E-2μbar

The screenshot shows the Microsoft Excel interface with the following elements:

- Title Bar:** BTM-Calculator Berlin.xlsm [Schreibgeschützt] - Microsoft Excel nichtkommerzielle Verwendung
- Menu Bar:** Datei, Start, Einfügen, Seitenlayout, Formeln, Daten, Überprüfen, Ansicht
- Left Ribbon:**
 - Speichern (Save)
 - Speichern unter (Save As)
 - Öffnen (Open)
 - Schließen (Close)
 - Informationen (Information)** - Active
 - Zuletzt verwendet (Recently Used)
 - Neu (New)
 - Drucken (Print)
 - Speichern und Senden (Save and Send)
 - Hilfe (Help)
 - Optionen (Options)
 - Beenden (Quit)
- Main Content Area:**

Informationen zu BTM-Calculator Berlin

D:\BTM-Calculator Berlin.xlsm

Sicherheitswarnung

Der aktive Inhalt enthält möglicherweise Viren und andere Sicherheitsrisiken. Der folgende Inhalt wurde deaktiviert:

 - Makros

Sie sollten Inhalt nur aktivieren, wenn Sie dem Inhalt der Datei vertrauen.

Einstellungen für das Sicherheitscenter

[Weitere Informationen zu aktiven Inhalten](#)

Schreibgeschützte Arbeitsmappe

Diese Arbeitsmappe wurde im schreibgeschützten Modus geöffnet. An der ursprünglichen Arbeitsmappe können keine Änderungen vorgenommen werden. Erstellen Sie eine neue Kopie der Arbeitsmappe, um die Änderungen zu speichern.

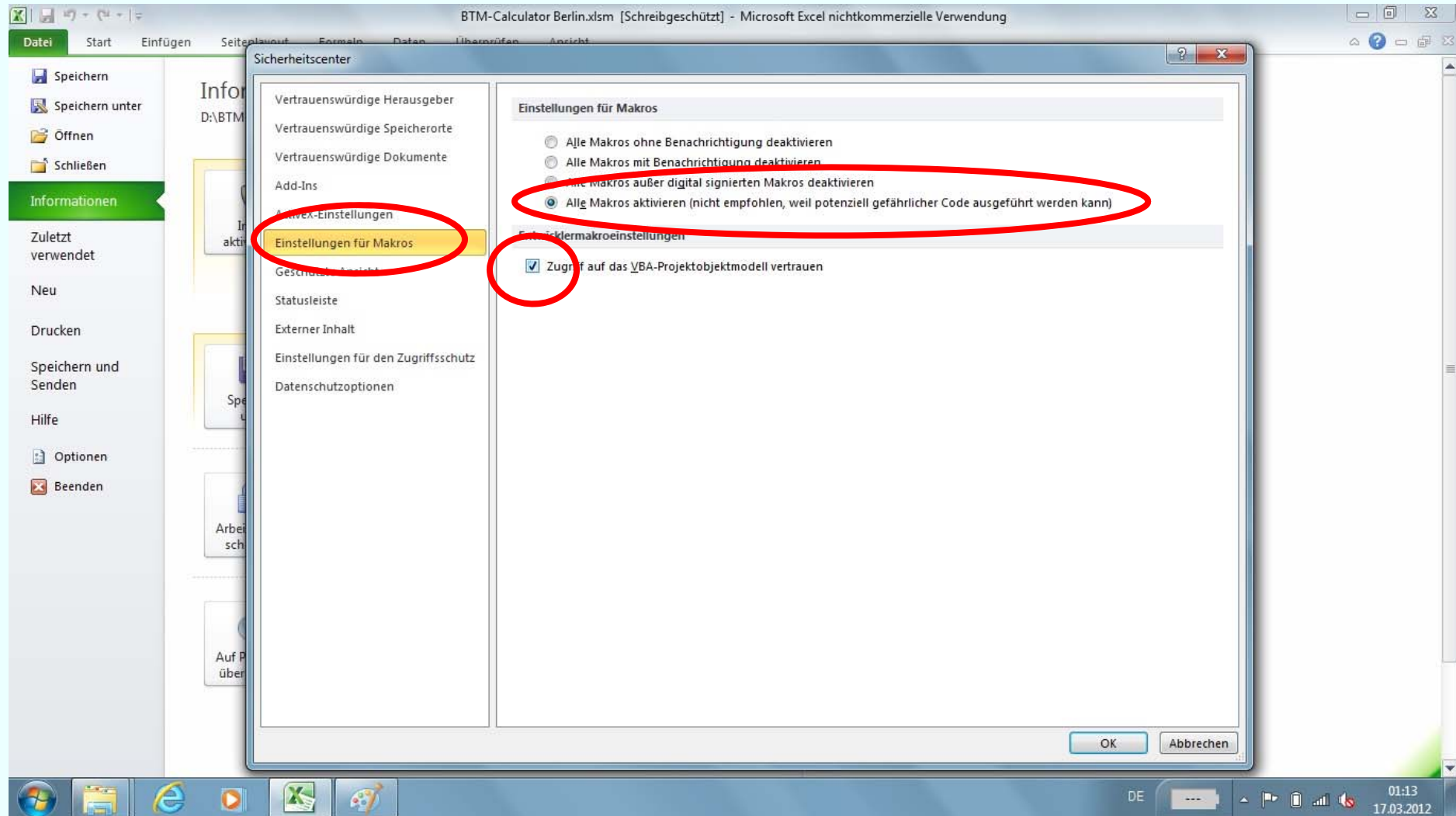
Berechtigungen

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Für die Freigabe vorbereiten

Bevor Sie diese Datei freigeben, machen Sie sich bewusst, dass sie Folgendes enthält:

 - Kommentare
 - Dokumenteigenschaften, Druckerpfad, Name des Autors und Verwandte Datumsangaben
 - Unsichtbare Objekte
 - Inhalte, die von Personen mit Behinderungen nicht gelesen werden können
- Right Ribbon:**
 - Eigenschaften (Properties)**
 - Größe: 64,4KB
 - Titel: Titel hinzufügen
 - Kategorien: Tag hinzufügen
 - Kategorien: Kategorie hinzufügen
 - Verwandte Datumsangaben (Related Dates)**
 - Letzte Änderung: 28.10.2011 00:59
 - Erstellt: 06.03.2007 18:04
 - Zuletzt gedruckt: 03.05.2007 09:57
 - Verwandte Personen (Related People)**
 - Autor: Georg Frinke
 - Autor hinzufügen
 - Zuletzt geändert von: Georg Frinke
 - Verwandte Dokumente (Related Documents)**
 - Dateispeicherort öffnen
 - [Alle Eigenschaften anzeigen](#)
- Taskbar:** Windows Start button, File Explorer, Internet Explorer, Media Center, Excel, Paint, System tray (DE, network, volume, date: 01:12 17.03.2012)



BTM-Calculator Berlin.xlsm [Schreibgeschützt] - Microsoft Excel nichtkommerzielle Verwendung

Excel-Optionen

Microsoft Office-Add-Ins anzeigen und verwalten.

Add-Ins

Name	Ort	Typ
Aktive Anwendungs-Add-Ins <i>Keine aktiven Anwendungs-Add-Ins</i>		
Inaktive Anwendungs-Add-Ins		
Analyse-Funktionen	C:\...ffice\Office14\Library\Analysis\ANALYS32.XLL	Excel-Add-In
Analyse-Funktionen - VBA	C:\...ffice\Office14\Library\Analysis\ATPVBAEN.XLAM	Excel-Add-In
Ausgeblendete Arbeitsblätter	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	Dokumentprüfung
Ausgeblendete Zeilen und Spalten	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	Dokumentprüfung
Benutzerdefinierte XML-Daten	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	Dokumentprüfung
Datum (XML)	C:\... Files\microsoft shared\Smart Tag\MOFL.DLL	Aktion
Eurowährungstools	C:\...soft Office\Office14\Library\EUROTOOL.XLAM	Excel-Add-In
Kopf- und Fußzeilen	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	Dokumentprüfung
Microsoft Actions Pane 3	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	XML-Erweiterungspaket
Nicht sichtbarer Inhalt	C:\... (x86)\Microsoft Office\Office14\OFFRHD.DLL	Dokumentprüfung
Solver	C:\...ffice\Office14\Library\SOLVER\SOLVER.XLAM	Excel-Add-In
Dokumentbezogene Add-Ins <i>Keine dokumentbezogenen Add-Ins</i>		
Deaktivierte Anwendungs-Add-Ins <i>Keine deaktivierten Anwendungs-Add-Ins</i>		
Add-In:	Analyse-Funktionen	
Herausgeber:	Microsoft Corporation	
Kompatibilität:	Es sind keine Kompatibilitätsinformationen verfügbar.	
Ort:	C:\Program Files (x86)\Microsoft Office\Office14\Library\Analysis\ANALYS32.XLL	
Beschreibung:	Stellt Tools zur Datenanalyse für statistische und technische Analysen bereit.	

Verwalte: Excel-Add-Ins Gehe zu...

The screenshot shows the Microsoft Excel interface with the 'Add-Ins' dialog box open. The 'Solver' option is checked and highlighted with a red circle. The background spreadsheet contains the following data:

Row	Parameter	Value	Unit
2	P ₀	8,1E-2mbar	
3	T _{shelf}	0,0°C	
4	N	210 Vials	
5	D _{vial}	28 mm	2,8cm
6	Vial thickness	1 mm	0,1cm
7	A _p	5,31cm ²	
8	V _{chamber}	66 l	6,60E-2m ³
9	Filling height	8 mm	0,8cm
14	Filling	3,0g	
15	Concentration	5%	
16	Solid Content	31,5g	3,15E-2kg
18	Pressure Rise	2,0E-1mbar	2,0E+2μbar
19	Δt	24,0s	
20	ER	4,9E-2μbar	

The 'Add-Ins' dialog box lists the following available add-ins:

- Analyse-Funktionen
- Analyse-Funktionen - VBA
- Eurowährungs-Tools
- Solver

The Solver description reads: 'Tool zum Optimieren und Berechnen von Formeln'.

The screenshot shows the Microsoft Excel interface with the 'View' (Ansicht) ribbon selected. The 'Macros anzeigen' (Show Macros) button is circled in red. The spreadsheet contains the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1						Fit								
2	P ₀	8,1E-2mbar			P _{Ice}	2,5E-1mbar	1,8E-1Torr				1,333mbar/Torr			
3	Θ _{shelf}	0,0°C	273,2K		K1	3,5E-1[1/K s]					273,15			
4	N	210 Vials			K2	1,3E-3mbar/s								
5	D _{Vial}	28 mm	2,8cm											
6	Vial thickness	1 mm	0,1cm		RMS	11,70								
7	A _p	5,31cm ²												
8	V _{chamber}	66 l	6,60E-2m ³		T _{Ice}	-34,1°C								
9	Filling height	8 mm	0,8cm		T _{shelf}	0,0°C								
10														
11					R _p	2,87E+1cm ² mbar h/g			Leak rate		5,00E-3 mbar x l / s			
12					EX	1,3E-3mbar/s					7,6E-5mbar/s	5,7E-5Torr/s		
13											1,8E-3mbar			
14	Filling	3,0g			Clean Table									
15	Concentration	5%												
16	Solid Content	31,5g	3,15E-2kg											
17														
18	Pressure Rise	2,0E-1mbar	2,0E+2μbar		Ice Temperature Fit									
19	Δt	24,0s												
20	ER	4,9E-2μbar												
21														
22														
23														
24														

BTM-Calculator Berlin.xlsm [Schreibgeschützt] - Microsoft Excel nichtkommerzielle Verwendung

File Start Einfügen Seitenlayout Formeln Daten Überprüfen Ansicht

Normal Seitenlayout Umbruchvorschau Benutzerdef. Ansichten Ganzer Bildschirm Arbeitsmappenansichten

Lineal Bearbeitungsleiste Gitternetzlinien Überschriften Anzeigen

Zoom 100 % Fenster einfrieren Neues Fenster Alle Fenster anordnen Fenster einfrieren Fenster Ausblenden Einblenden Fensterposition zurücksetzen Fenster

Aufgabenber. speichern Fenster wechseln Makros

	A	B	C	D	E	F	L	M	N	O	P
1					Fit						
2	P ₀	8,1E-2mbar		P _{Ice}		2,5					
3	g _{shelf}	0,0°C	273,2K	K1		3					
4	N	210 Vials		K2							
5	D _{vial}	28 mm	2,8cm								
6	Vial thickness	1 mm	0,1cm	RMS							
7	A _p	5,31cm ²									
8	V _{chamber}	66 l	6,60E-2m ³	T _{Ice}							
9	Filling height	8 mm	0,8cm	T _{shelf}							
10											
11				R _p		2,87E+1cm					
12				EX		1,3					
13											
14	Filling	3,0g									
15	Concentration	5%									
16	Solid Content	31,5g	3,15E-2kg								
17											
18	Pressure Rise	2,0E-1mbar	2,0E+2μbar								
19	Δt	24,0s									
20	ER	4,9E-2μbar									
21											
22											
23											
24											

Ice Temperature Fit

Cockpit Input Diagram Example 01 Example 02 Example 03 Example 04 Example 05 Example 06 Examp|

Bereit 100 % 02:17 17.03.2012

Makro

Makroname:

- Iterate
- Clean_table
- Iterate

Ausführen Schritt Bearbeiten Erstellen Löschen Optionen... Abbrechen

Makros in: Alle offenen Arbeitsmappen

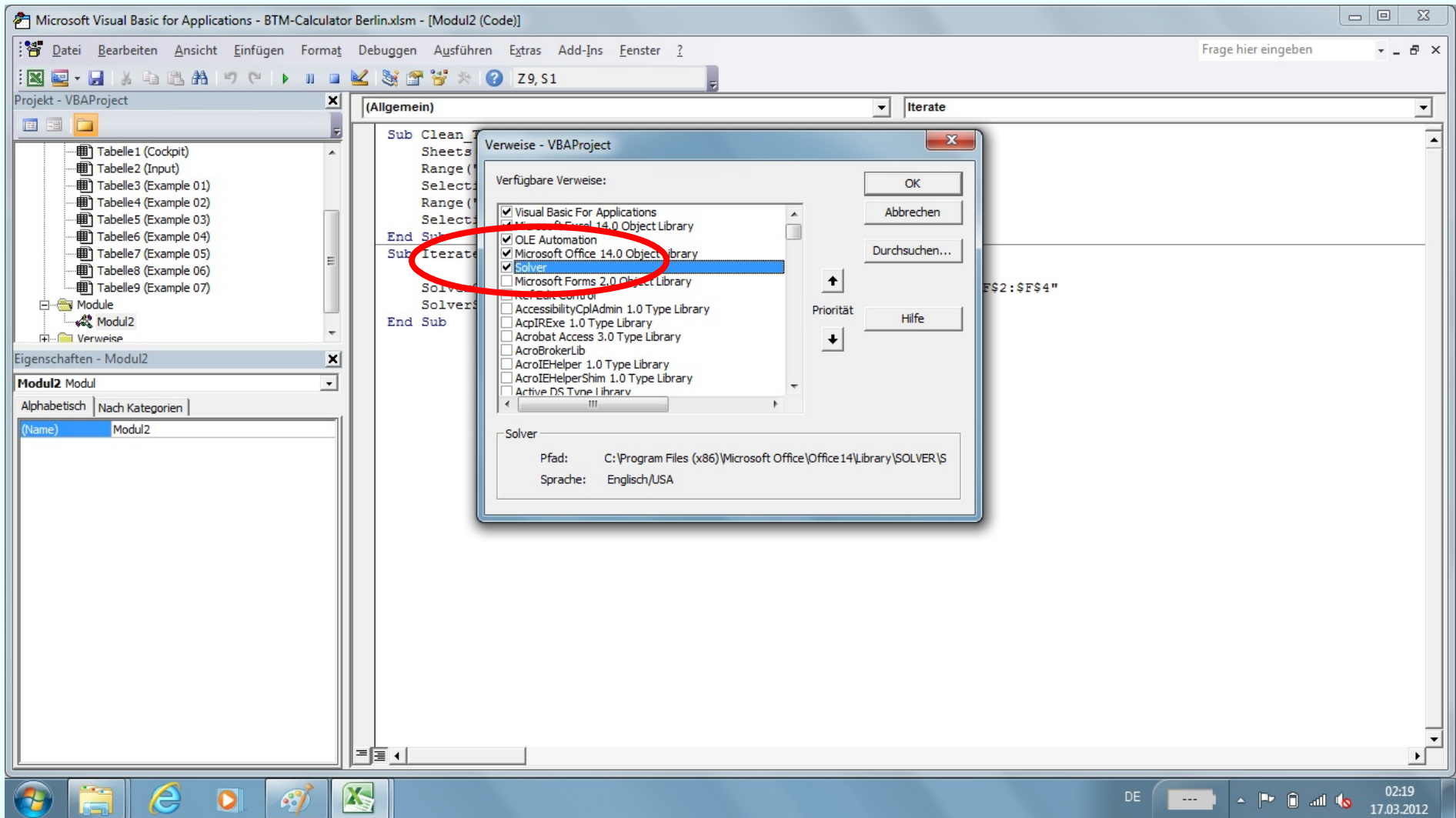
Beschreibung

The screenshot shows the Microsoft Visual Basic for Applications environment. The 'Extras' menu is open, with 'Verweise...' highlighted. The code editor contains the following VBA code:

```
Sub Clean_Tab...  
Sheets ("I...  
Range ("A2...  
Selection...  
Range ("C3...  
Selection.ClearContents  
End Sub  
  
Sub Iterate ()  
  
SolverOk SetCell:="$F$6", MaxMinVal:=2, ValueOf:="0", ByChange:="$F$2:$F$4"  
SolverSolve  
End Sub
```

The Properties window for 'Tabelle1' shows the following settings:

(Name)	Tabelle1
DisplayPageBreaks	False
DisplayRightToLeft	False
EnableAutoFilter	False
EnableCalculation	True
EnableFormatConditionsCalculation	True
EnableOutlining	False
EnablePivotTable	False
EnableSelection	0 - xlNoRestrictions
Name	Cockpit
ScrollArea	
StandardWidth	10,71
Visible	-1 - xlSheetVisible



Then close all windows, except Excel table

...Run “solver” once manually...

..and careful listen to the further explanations of the instructor