Zimmer

PET-Polycondensation plant

Training

January, 2005

Mr. Deisinger T-VT

PET-Polycondensation plant

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Polyester plant, Spain

PET-Polycondensation plant

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Polyester plant, Saudi Arabia

PET-Polycondensation plant

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Polyester plant, China

PET-Polycondensation plant

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Polyester plant, Germany

Application of bottle PET (examples)

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Contents

1. Zimmer`s Core Competencies and Capabilities

Inventions and Competencies

- Direct Spinning
- Total EG recycling
- Commercial use of EG Jet
- SSP
- By friction heated DRR
- Driving force for high capacities
- Heavy metal free catalyst
- DHI and DTP technology

Capabilities, Facts and Figures

- Successful start for more than 168 plants
- Sold single line capacities up to 660 t/day
- Direct spinning plants up to 1000 t/day
- Design for continuous PET plant up to 1320 t/day
- Annual Down-Time < 0,6%
- Discontinuous PET plant up to 100 t/day
- SSP plant up to 600 t/day (single line)
- New PTT process with 300 t/day production

→ **High competence shown since many years**

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2. Zimmer`s reference list (executed projects) 1994 – 2004

1	x	660	t/d B	P. R. China	Changzhou Plastic Groups Corp.
2	x	400	t/d T/B	Egypt	Saudi Egyptian Petrochemical Company
1	x	400	t/d B	Europe	Dow
1	x	144	t/d T	India	JCT Limited
1	x	150	t/d T	India	Modern Petrofils
1	x	260	t/d T	India	Parasrampuria Synthetics Ltd.
1	x	51	t/d T	India	Pearl Engineering Polymers Ltd.
1	x	185	t/d T	India	Rajashree Polyfil Ltd.
1	x	400	t/d T	India	South Asian Petrochem Ltd.
1	x	630	t/d T	India	Reliance
1	x	300	t/d T	Indonesia	P.T. Luminary Polysindo
1	x	180	t/d B	Indonesia	P.T. Polypet Karyapersada
1	x	300	t/d T	Indonesia	Pacific Fibretama Corp.
3	x	360	t/d T	Iran	Petrochemical Industries
1	x	180	t/d B	Iran	Petrochemical Industries
1	x	180	t/d B	Italy	Shell

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2. Zimmer`s reference list (executed projects) 1994 – 2004

2	x	440	t/d	B	Lithuania	Petrochemical Holding
2	x	300	t/d	T	Malaysia	Hualon Corporation
2	x	300	t/d	T	Malaysia	Hualon Corporation
2	x	300	t/d	B	Malaysia	Hualon Corporation
1	x	240	t/d	T	Mexico	Fibrás Químicas
1	x	260	t/d	T	Pakistan	Dhan Fibres Ltd.
1	x	180	t/d	T	Pakistan	Ibrahim Fibres Ltd.
1	x	180	t/d	T	Pakistan	Gatron Industries
1	x	410	t/d	T	Pakistan	Ibrahim Fibres Ltd.
1	x	150	t/d	B	Russia	Chimwolokno Twer
1	x	440	t/d	B	Russia	Petrochemical Holding
1	x	120	t/d	T	Saudi Arabia	Arabian Industrial Fibers Co.
1	x	144	t/d	T	Saudi Arabia	Arabian Industrial Fibers Co.
1	x	121	t/d	T	Saudi Arabia	Arabian Industrial Fibers Co.
1	x	60	t/d	B	Saudi Arabia	Arabian Industrial Fibers Co.
1	x	200	t/d	T	South Korea	Dae Han Synthetic Fiber Co. Ltd.

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2. Zimmer`s reference list (executed projects) 1994 – 2004

2	x	250	t/d	T	South Korea	Han Kook Synthetics Inc.
1	x	32	t/d	T	South Korea	Han Kook Synthetics Inc.
1	x	250	t/d	B	South Korea	Sam Yang Co.
1	x	240	t/d	B	Spain	La Seda de Barcelona
1	x	240	t/d	B	Spain	Brilen S.A.
1	x	330	t/d	B	Spain	Brilen S.A.
1	x	300	t/d	T	Taiwan	Chia Hsin Flour, Feed and Vegetable Oil Corp.
1	x	30	t/d	T	Taiwan	Chia Hsin Flour, Feed and Vegetable Oil Corp.
1	x	300	t/d	T	Taiwan	Houng Chou Chemical
1	x	300	t/d	T	Taiwan	Tainan Spinning Co.
1	x	400	t/d	T	Taiwan	Chung Shing Text.
1	x	200	t/d		Taiwan	Chang Chun Plastics Co. (PBT)
1	x	300	t/d	B	Thailand	Bangkok Polyester Co. Ltd.
1	x	250	t/d	T	Thailand	Shinkong Synthetic Fiber Corporation
1	x	300	t/d	T	Thailand	Kangwal Text. Com.
1	x	250	t/d	B	Thailand	AsiaPET

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2. Zimmer`s reference list (executed projects) 1994 – 2004

1	x	300	t/d B	Thailand	Mitsui Chemicals Inc.
1	x	360	t/d T	Turkey	Korteks
1	x	120	t/d B	USA	Tolaram Polymers Inc.
1	x	268	t/d T	USA	Wellman Inc.
3	x	300	t/d T	USA	Wellman Inc.
1	x	300	t/d	USA	Shell (PTT)
1	x	180	t/d B	USA	Tiepet

3. Historical development of Zimmer's continuous PET-process (staging of process)

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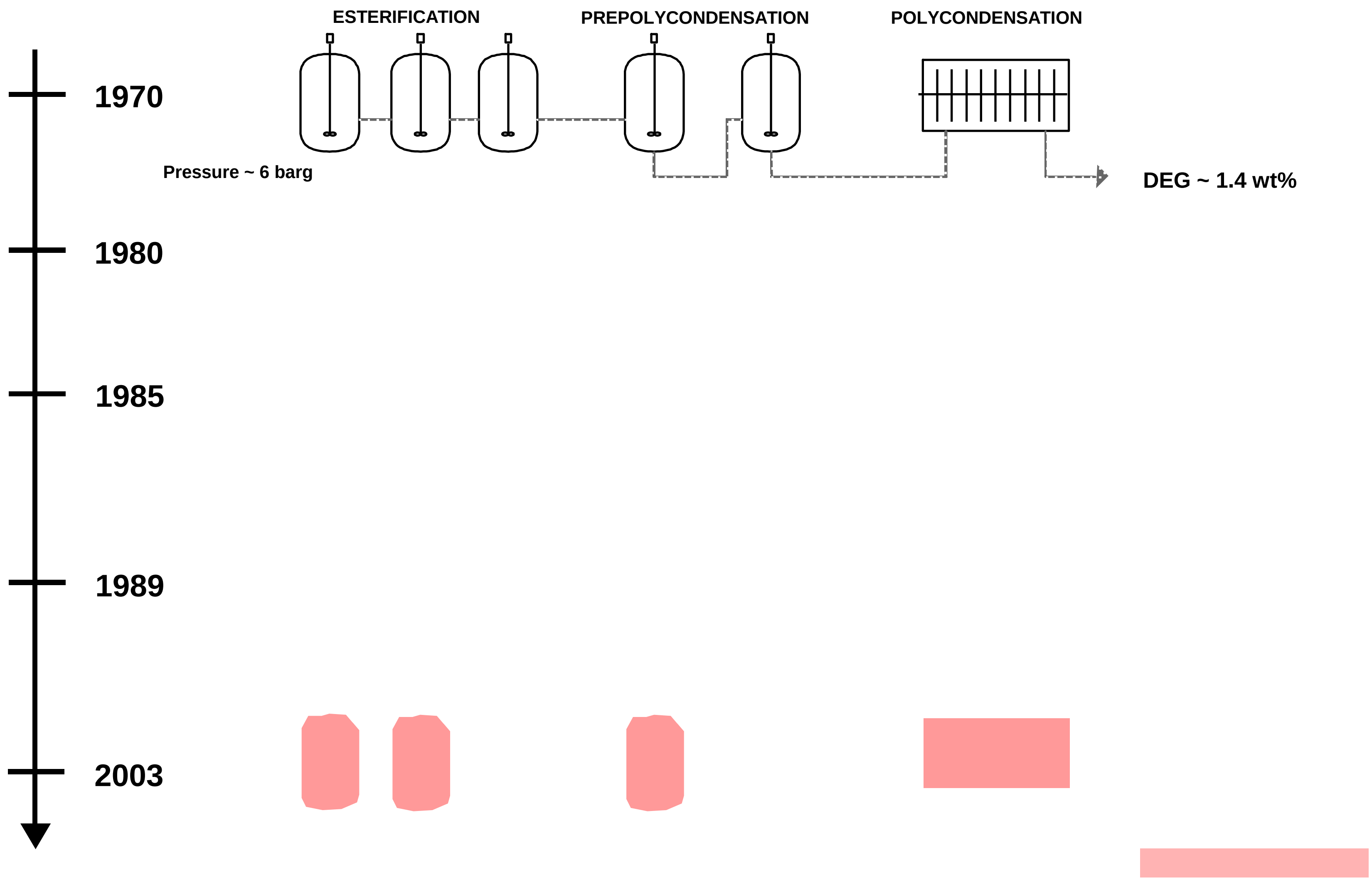


What can be shown by this historical development ?

1. By reducing the process temperature (increasing the residence time)

   - the process has become more stable
   - the amount of side products was reduced

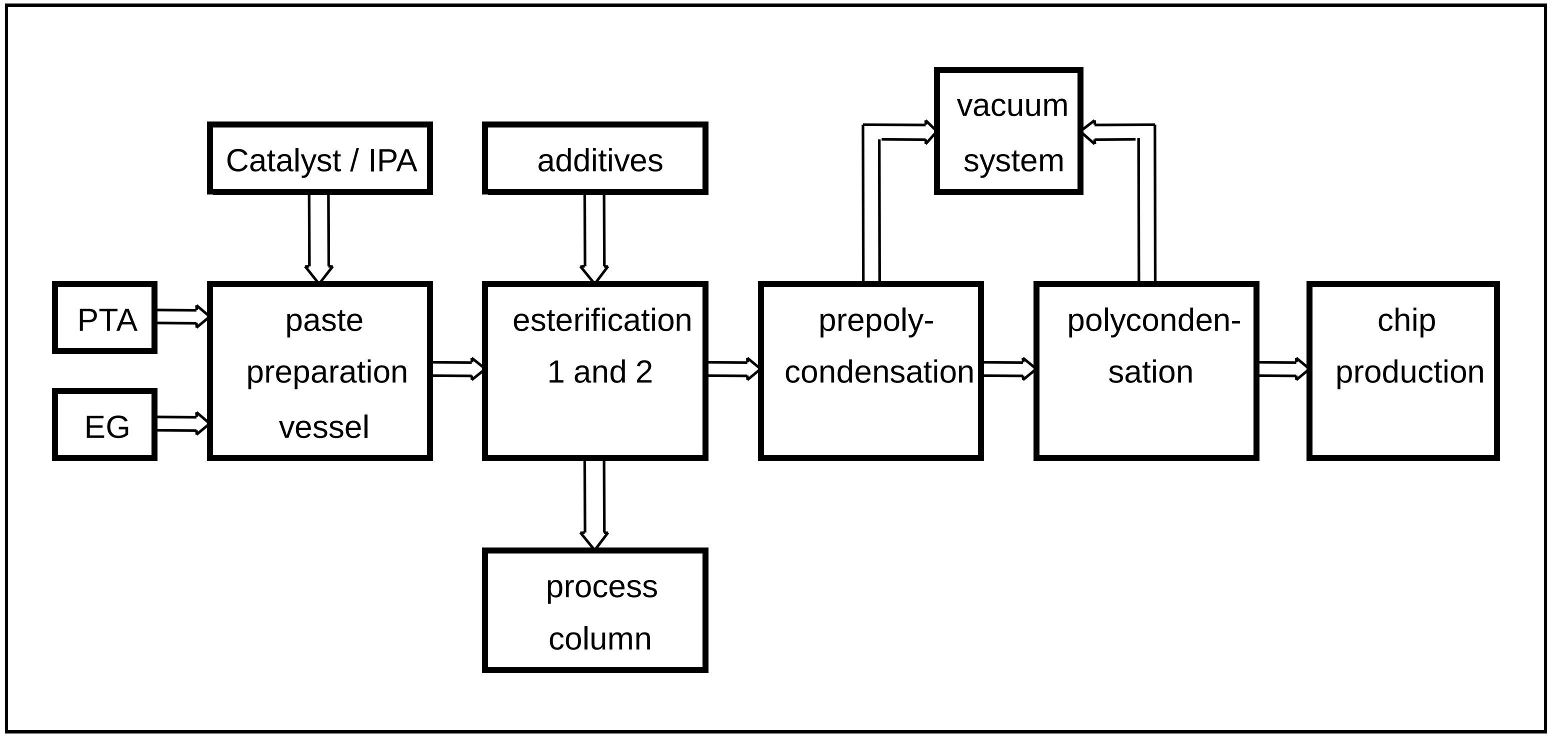
2. Cascading of process was improved

3. Efficiency of poly reactors was improved

General Philosophy and Background for the Main Equipment in a PET- Plant :

The four consecutive process stages are:

- ❑ Esterification 1
- ❑ Esterification 2
- ❑ Prepolycondensation
- ❑ Polycondensation



The basic chemicals of bottle PET process:

- Pure terephthalic acid (PTA) - $COOH\text{-}C_6H_4\text{-}COOH$
- Mono ethylene glycol (EG) - $HO\text{-}C_2H_4\text{-}OH$
- Pure isophthalic acid (IPA) - $COOH\text{-}C_6H_4\text{-}COOH$
- Antimontriacetat (Catalyst) - $Sb_2(CH_3COO_3)$
- Bluetoner
- Diethylene glycol (DEG) - $HO\text{-}C_2H_4\text{-}O\text{-}C_2H_4\text{-}OH$
- Cobaltacetat (colour additive) - $Co(CH_3COO)_2$
- Phosphoric acid (Heat stabilizer) - H_3PO_4

4.1. Paste Preparation :

- **Main Purpose :**
  - To form a homogeneous mixture of raw materials
    - PTA / IPA = solid powder
    - EG = medium viscose liquid
    - Paste = tixotropic slurry, solidifies at approx. 60°C / MR 1,05

- **Includes :**
  - Exact dosing of raw materials
    - PTA / IPA by weighing
    - EG / Additive by flow control

$$MR_{FEED} := \left(\frac{m_{EG}}{m_{PTA}}\right) \cdot \left(\frac{M_{PTA}}{M_{EG}}\right) \quad \text{(usually 1,05 - 1,15)}$$

Exact molar ratio is important for process tuning and economical operation.

4.2. Esterification :

- **Main Purpose :**
  - To esterify PTA and EG in melt phase
  - build up of the first chain length

$$\textbf{acid + alcohol} \underset{\text{saponification}}{\overset{\text{esterification}}{\rightleftharpoons}} \textbf{ester + water}$$

- **Stoichiometric reaction which demands reaction volume (Residence Time) and ideal mixing**
  - this implements agitated vessel design
- **To force into esterification direction (DGT) water need to be removed**
  - this implements a rectification column to separate reaction water

4.2.1. Esterification, Definition of Internal Molar Ratio :

- **To force the reaction further into esterification, the EG concentration need to be increased.**
  - This implements back feed of EG out of the column sump into the esterification reactor

MRI = all fed EG- amounts into a reactor against all fed PTA / IPA- amounts, independent of any discharge flow.

For example for EST1 :

$$MRI := \left(\frac{m_{EG\_Paste} + m_{EG\_Column}}{m_{PTA\_Paste}} \right) \cdot \frac{M_{PTA}}{M_{EG}}$$

4.3. Prepolycondensation :

Main Purpose :

- To remove excess EG coming from esterification part
- To start main polycondensation reaction

$$\text{C+C+C+C+C} \xrightarrow{\text{Catalyst, Temp}} \text{C´-C´-C´-C´-C´} + \text{A+A+A+A+A}$$

or

$$\text{C´-[-C´]}_{(n-2)}\text{-C´} + n*\text{A}$$

C = esterification product (DGT)
A = ethylene glycol (EG)

- this implements staged reactor design as the PP (several chambers)

4.3.1. Prepolycondensation, Vacuum System :

- **To force the reaction into polycondensation EG need to be removed.**
  - This implements introduction of vacuum suction.
- **Main Purpose of the Vacuum System :**
  - Condensation of the vapours out of the specific reactor
  - Generation of controlled vacuum
- **Condensation with the same medium as the process vapours allows easy recycling of excess / split EG**
- **Generation of vacuum with EG-jet and vacuum pumps**

This leads to an environmentally friendly process.

4.4. Polycondensation :

- **Main Purpose :**
  - To perform the main polycondensation reaction
  - To finalise base product quality

$$2n\ \text{PETshort} \rightleftharpoons n\ \text{PETfinal} + n\ \text{EG}$$

$$K := \frac{(\text{PETfinal})\cdot(\text{EG})}{(\text{PETshort})^2}$$

- **Polycondensation reaction needs small reaction volume and plug flow condition**
  - this implements staged reactor design as the DRR (8 -10 chambers)

4.4. Polycondensation :

- **To force the reaction into chain length build up EG need to be removed.**
  - This implements reaction under higher vacuum.
- **Removal of EG out of a viscose liquid becomes a transportation problem**
  - This leads to a reactor design which creates large surfaces of the polymer melt under vacuum.
  - This is accomplished by using rotating disc rings which create a thin polymer film.

IV = f (τ, p, T, catalyst, surface area, etc.)

surface area = f (dynamic viscosity, design, rotating disc speed)

5. Zimmer's continuous process
4-reactor polycondensation process

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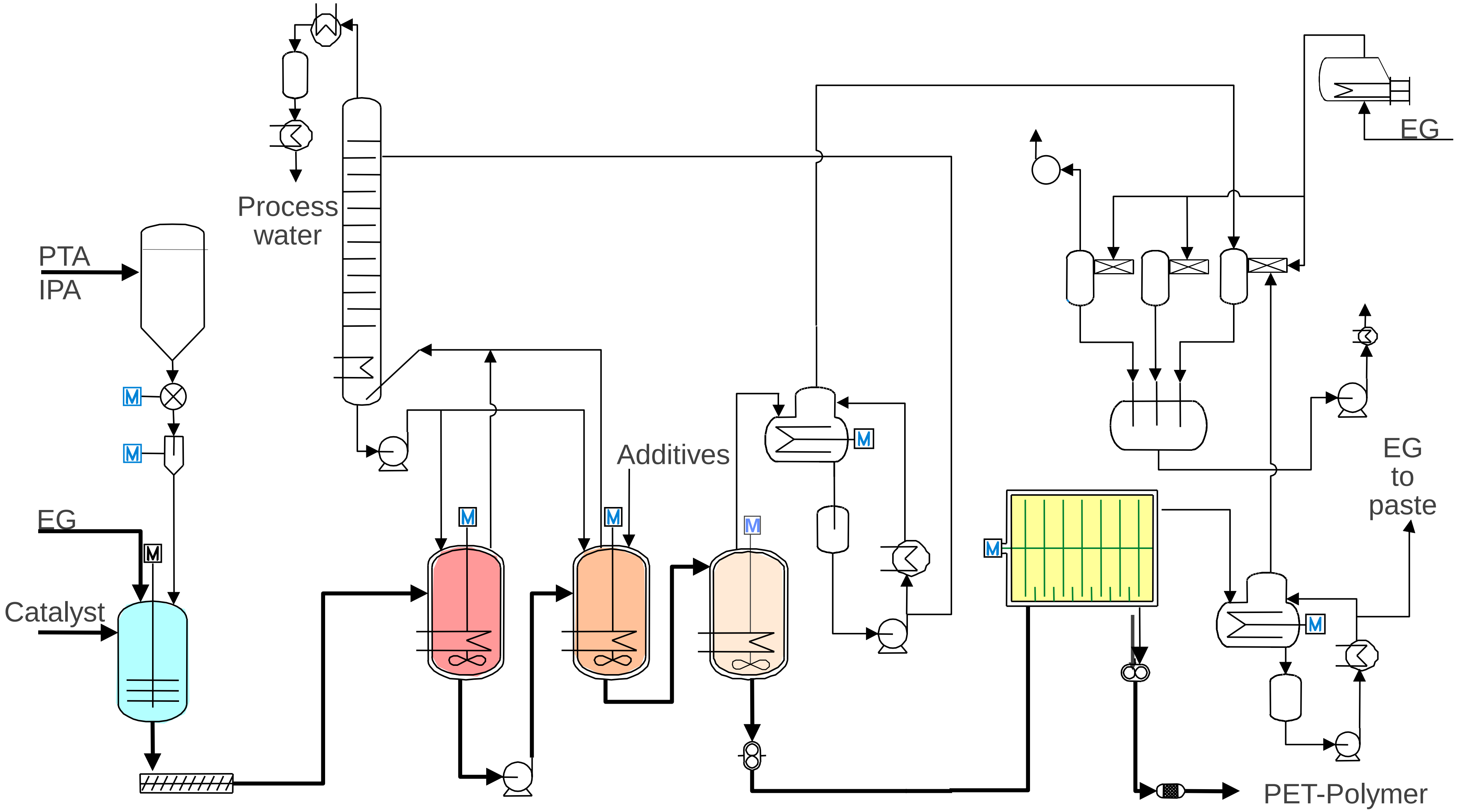
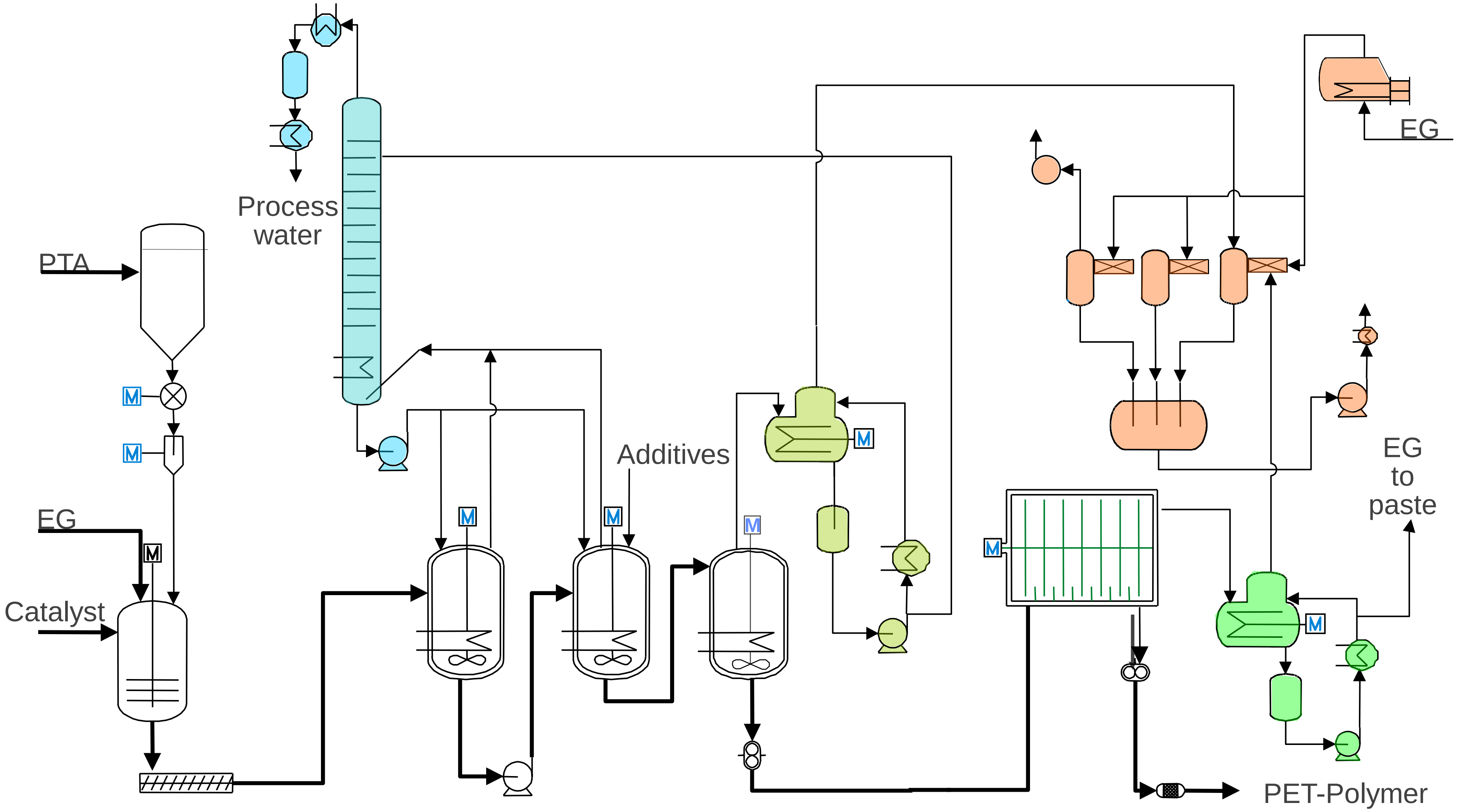
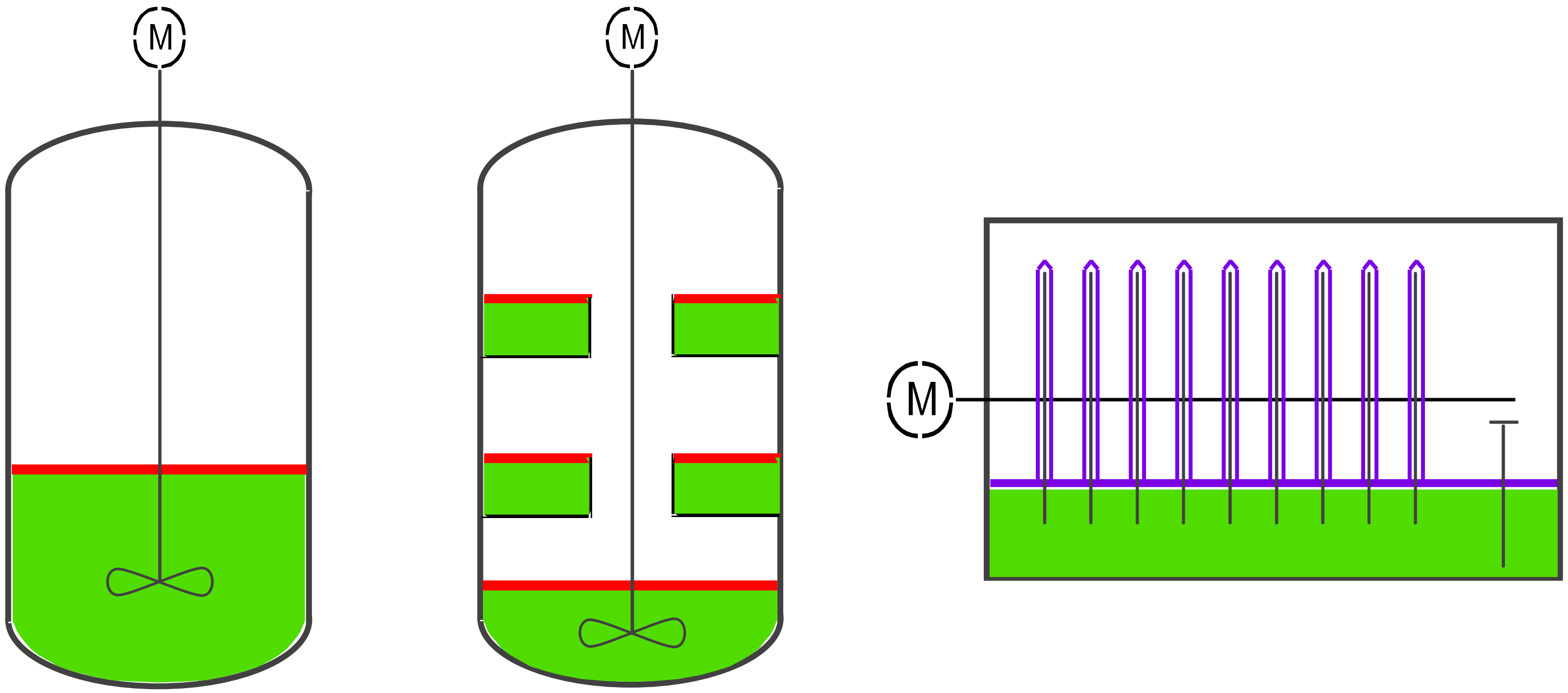


5. Zimmer's continuous process
4-reactor polycondensation process

Zimmer



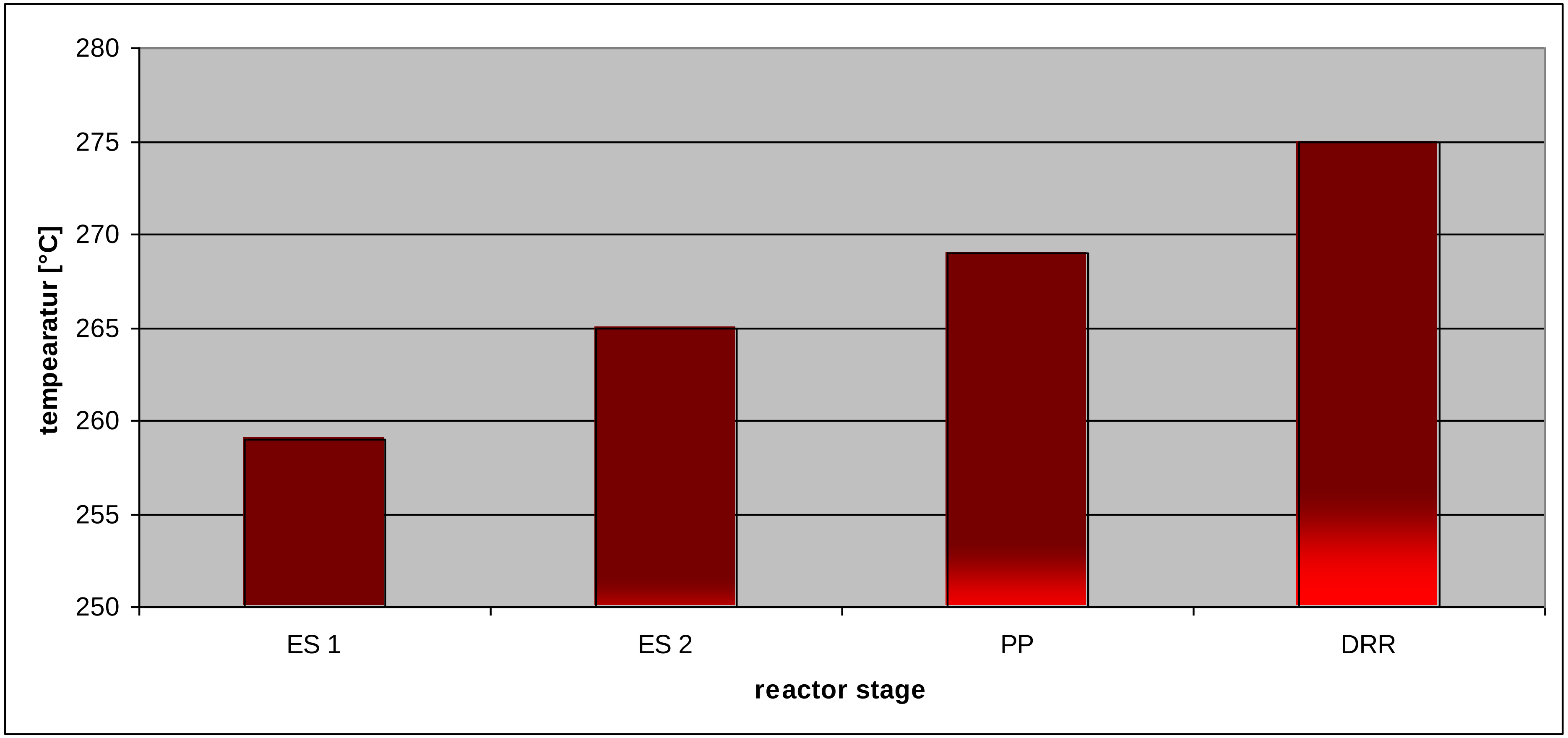


agitated reactors (esterification)

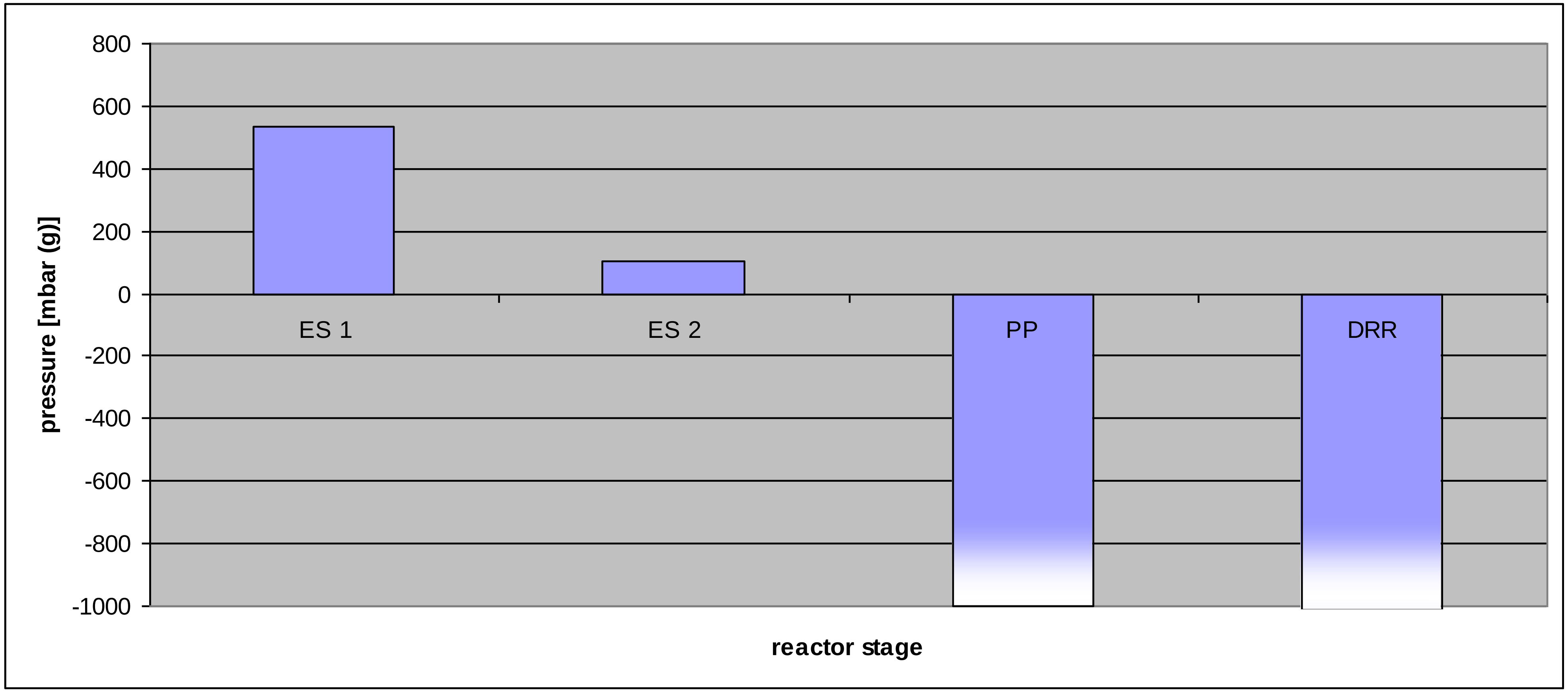
cascade reactor (prepolymerisation)

disc ring reactor

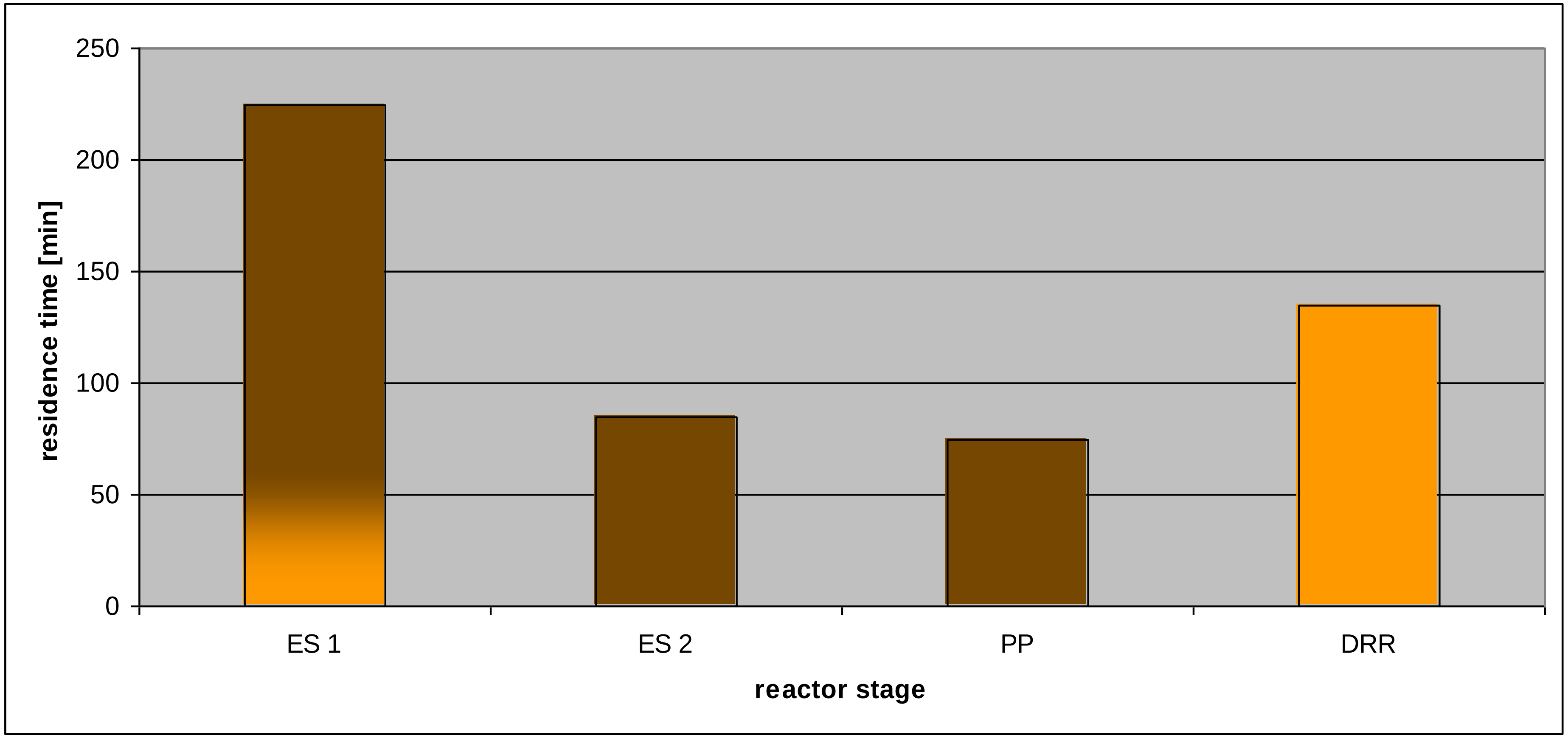
6.1. Temperature profile of reactors



6.2. Pressure Profile of reactors



6.3. Residence time of reactors



6.4 Typical values of process parameter

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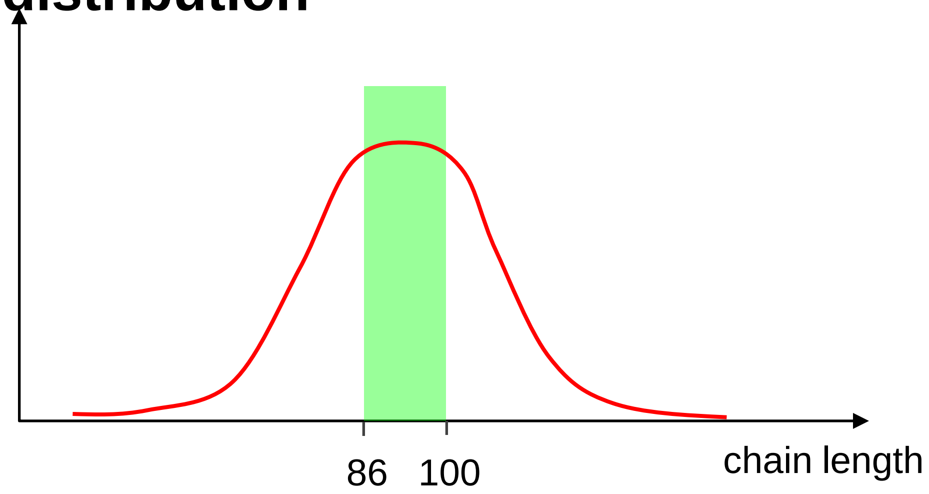
reactor	temperature [°C]	pressure [mbara]	residence time [min]	chain length	dynamic viscosity [Pas]	IV [dl/g]
esterification stage 1	259	1500	220	3 - 8	0.032	0.093
esterification stage 2	265	1115	85	5 - 10	0.033	0.097
prepolymerization stage	270	15	75	appr. 16	2 to 4	0,23
DRR	278	1	140	86 - 100	350	0.62

Schulz-Flory distribution



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6.5 Testing of DRR

Target: High efficient polycondensation reactors, to ensure :

low process temperature
low catalyst content

→ **high reactor activity coefficient**

Low temperature and extended residence time in reactors

- **operation close to equilibrium**
- **conversion rate**

Result:

- **very stable operation**
- **process is insensitive against**
  - minor process disturbances
  - minor utility fluctuations
  - minor operational errors
  - variation of raw material qualities

7. PET plant for bottle grade
Process parameters - Design: 400 t

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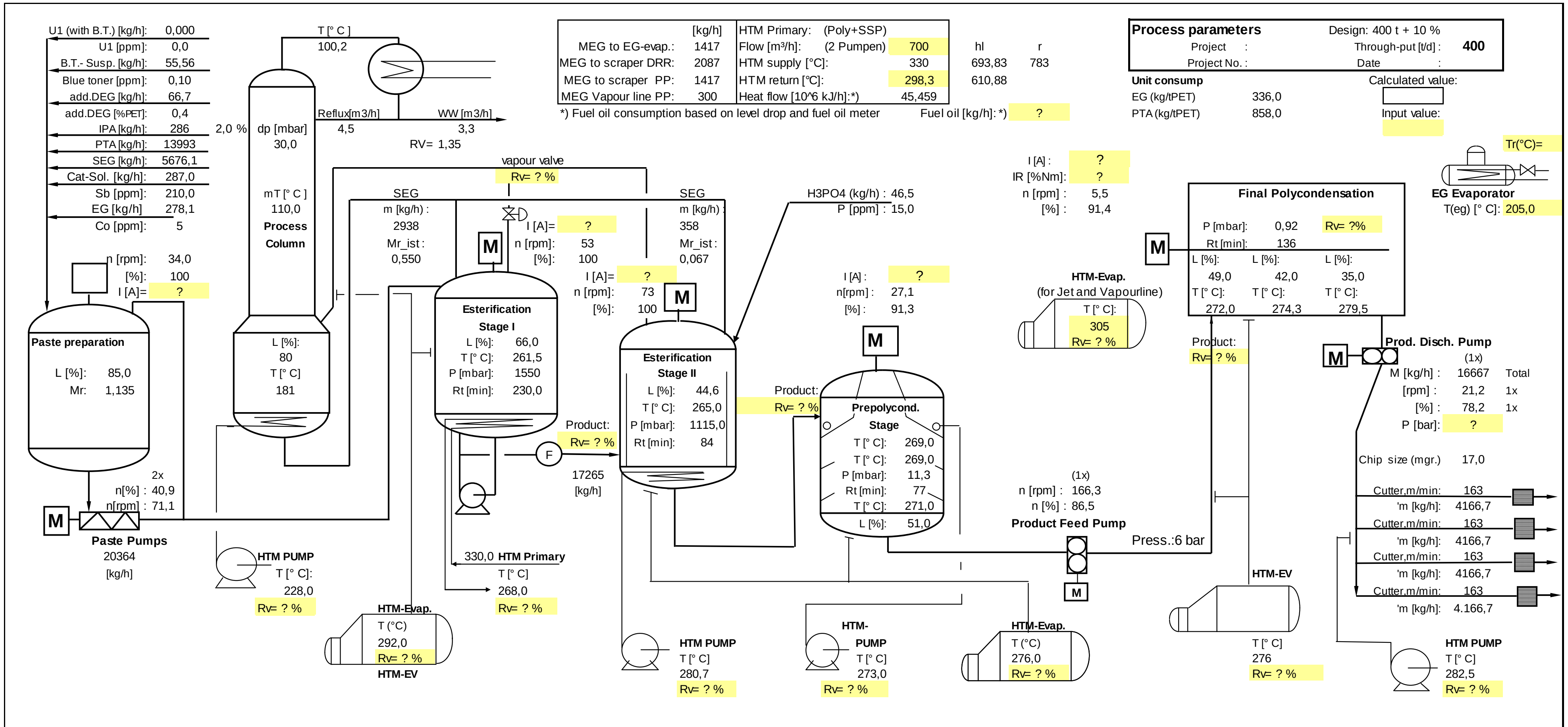


Zimmer		Esterification Stage I	Esterification Stage II		Prepoly cond. Stage		Finalpolycondensation		Chips	Finalpolycondensation	Chips
SN	[mg(KOH)/g]	564 `+/-3	562 `+/-2				Aceticaldehyde	ppm	51	DEG % wt	1,3
AN		48 `+/-3	21 `+/-4				Ash	[%]		H2O % wt	
CONV	[%]	91,5	96,3		COOH-Groop	85-90	COOH-Groop	[10-6 equ/g]	32 +/-2	IPA % wt	2
COOH-Groop	[10-6 equ/g]	855,6	374,3		Intrinsic Viscosity	0,25	Intrinsic Viscosity		0,62	Meltingpoint (C)	250
Intrinsic Viscosity							YI			Cristallizationp. (C)	
DEG	[%]	1,00	1,20			1,25	L :		85	Glasp. (C)	
Free EG	[%]						b :		-3,6 +/-0,3	NTU	
Residence time	[min]	230	84		Residencetime min.	77	a :		-0,4 +/-0,1	DRR Residencetime min.	136

Remark: The SP List can be changed according to actual requirements

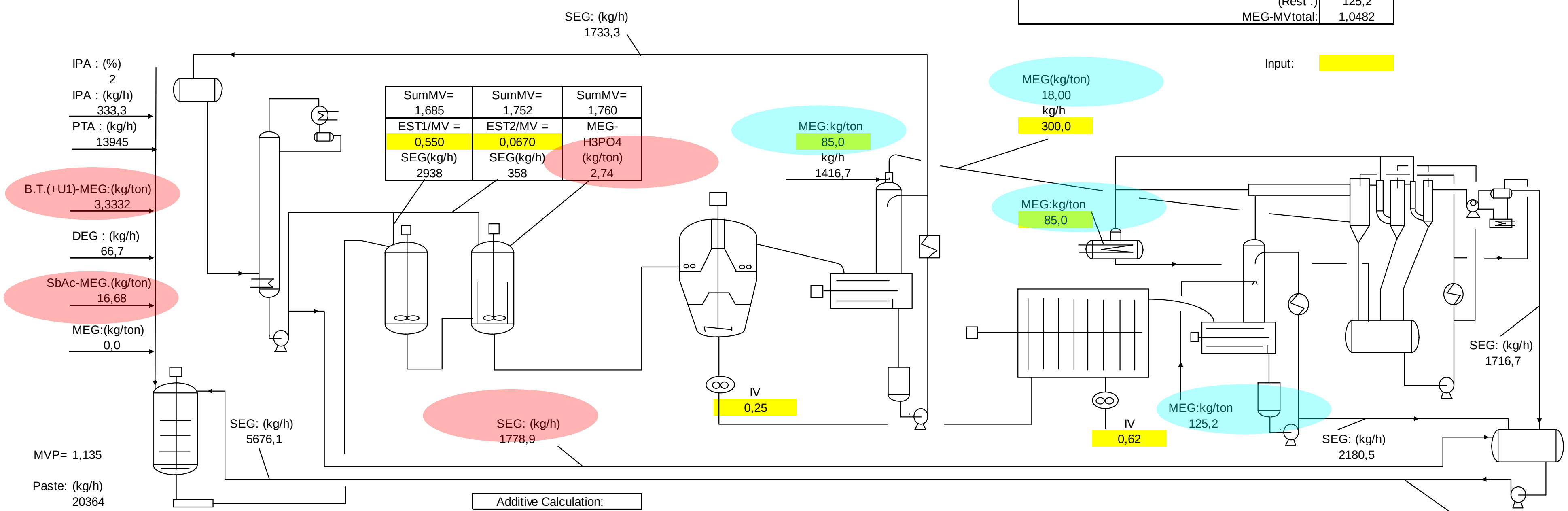
Remark: The HTM Temperatures are expected figures only and have to be adjusted acc. to the Product temperatures

7. PET plant for bottle grade
MEG management 4-stage PET-Process – 400 tato

Zimmer

to produce 1000 kg PET you need:
858 kg PTA/IPA
336 kg EG

4-Stufen PET-Process: (with compact PP)		Consumption:	kg/ton PET
		PTA:	**858**
		MEG:	**336**
Example:	**400** ton/day	(MEG-Calc.:)	210,8
		(Rest :)	125,2
		MEG-MVtotal:	1,0482



SEG-Feed
kg/h
5676,1
(total recycling)

Additive Calculation:

SbAc3 to Paste:		
Sb in PET:	210	ppm
SbAc3 in EG	3,0	Wt %
SbAc3:	0,5160	kg/Ton PET
Ansatz:	17,199	kg/Ton PET

Co in PET:	5,0	ppm
CoAc2+4H2C	0,0211	kg/Ton PET

DEG-Feed	0,40	Wt %
Feed	4,0	kg/Ton PET

Additive-MEG to paste:	
20,02	kg/ton

Total Additive-MEG:	
22,75	kg/ton

H3PO4 to VEII:		
P in PET:	15,0	ppm
H3PO4 in EG	2,0	Wt %
H3PO4:	0,0558	kg/Ton PET
Ansatz:	2,79	kg/Ton PET

Blue toner to Paste:		
B. T. in PET:	0,10	ppm
B. T. in EG:	0,0030	Wt %
B. T.	0,00010	kg/Ton PET
Ansatz:	3,3333	kg/Ton PET

total additive MEG
22,75 kg/ton

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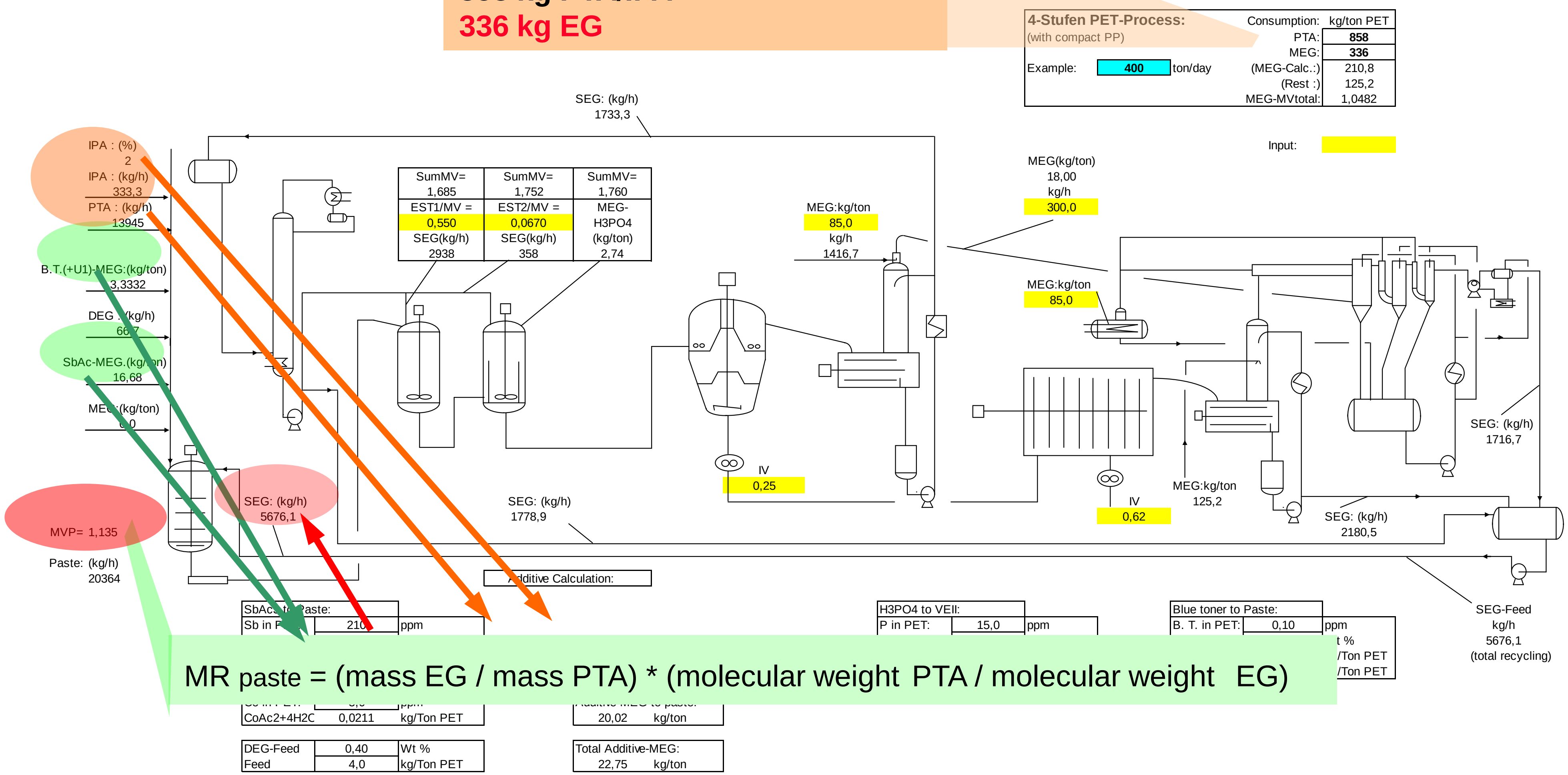

MR paste = (mass EG / mass PTA) * (molecular weight PTA / molecular weight EG)

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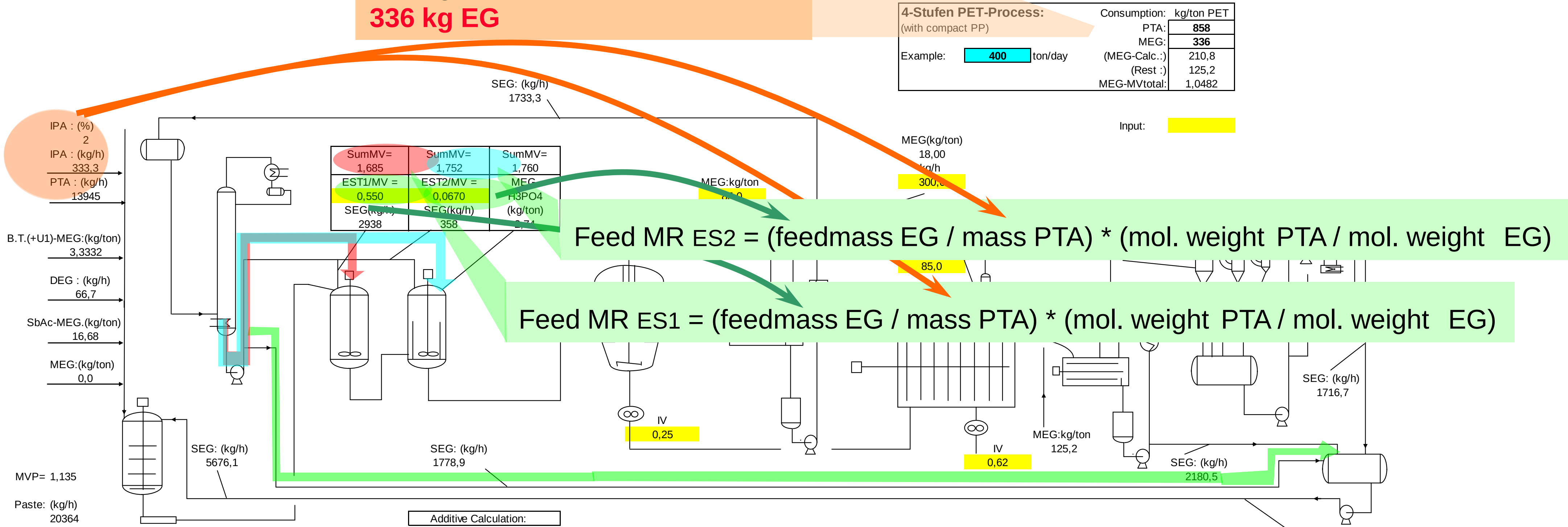

Feed MR ES2 = (feedmass EG / mass PTA) * (mol. weight PTA / mol. weight EG)

Feed MR ES1 = (feedmass EG / mass PTA) * (mol. weight PTA / mol. weight EG)

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Sb in PET:	210	ppm
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Co in PET:	5,0	ppm
CoAc2+4H2C	0,0211	kg/Ton PET

DEG-Feed	0,40	Wt %
Feed	4,0	kg/Ton PET

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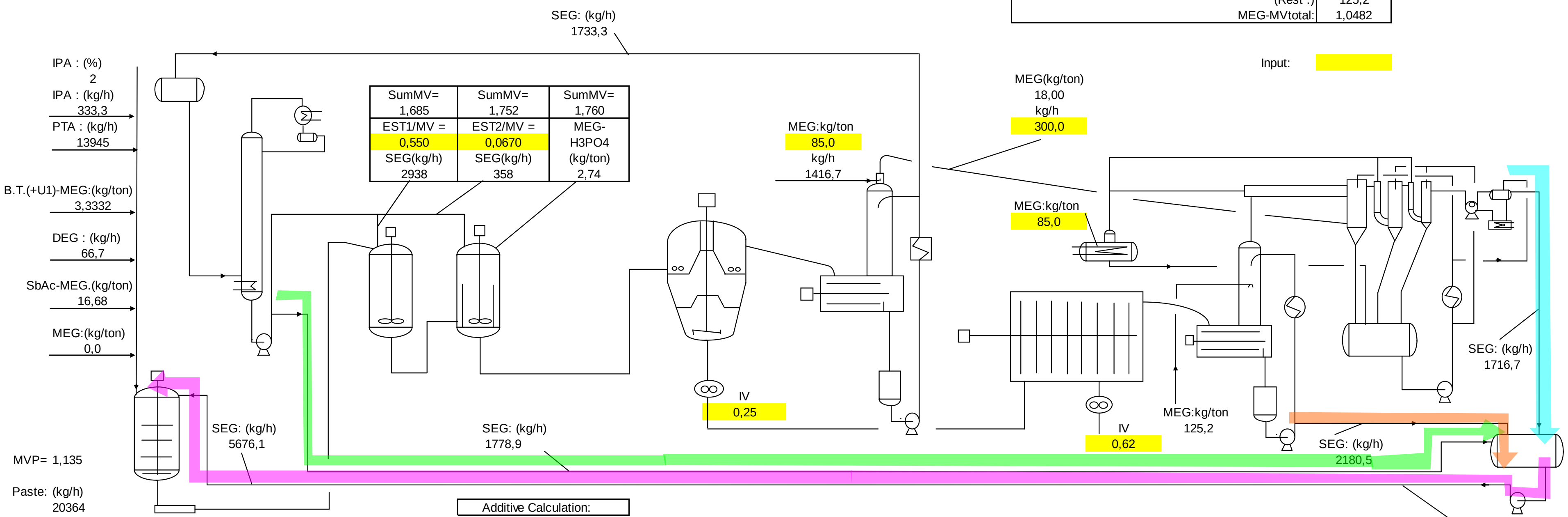

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Additive-MEG to paste:	
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Total Additive-MEG:	
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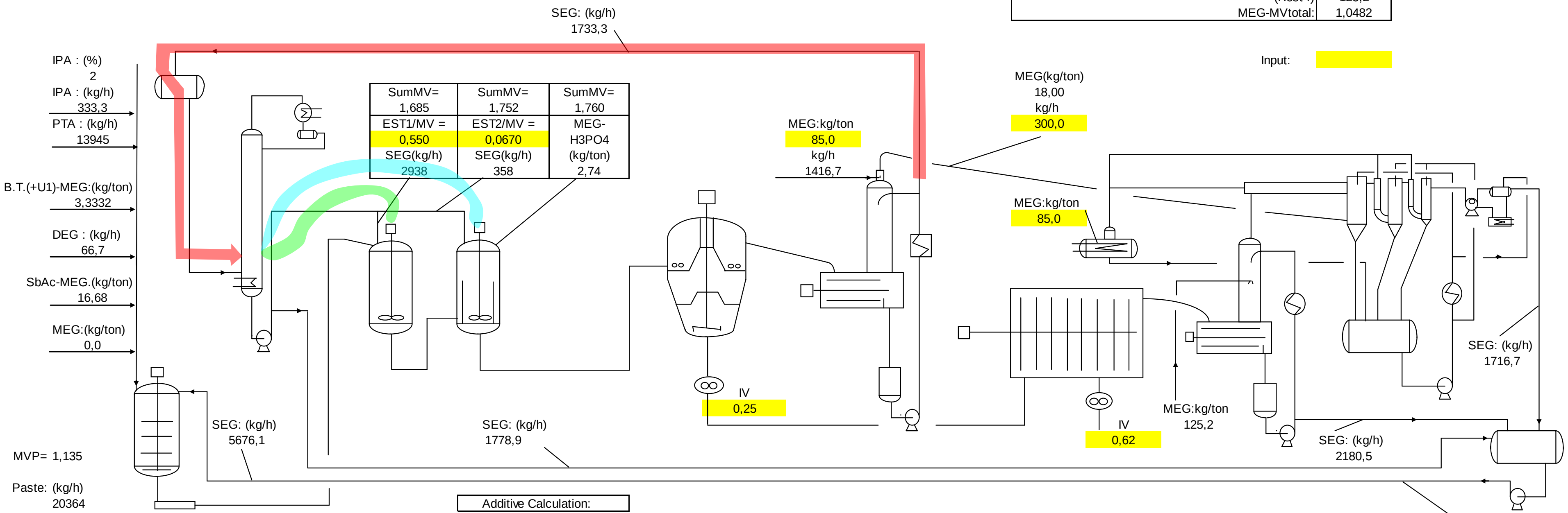

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Contents

- **Reaction in melt phase (non water system):**
  - requires temperature above melting point
  - because organic macromolecules will decompose with increasing temperature, temperature need to be minimized
  - therefore catalyst need to be used for reactions which would normally require extensive reaction temperature
- **Esterification reaction is a stoichiometric reaction between two components, PTA and EG**
  - requires ideal mixed reactors with large mix volume
- **Polycondensation reaction is a statistical reaction between molecules of the same nature but different chain length**
  - requires small reactor volume with plug flow conditions to form uniform macromolecules with high chain length

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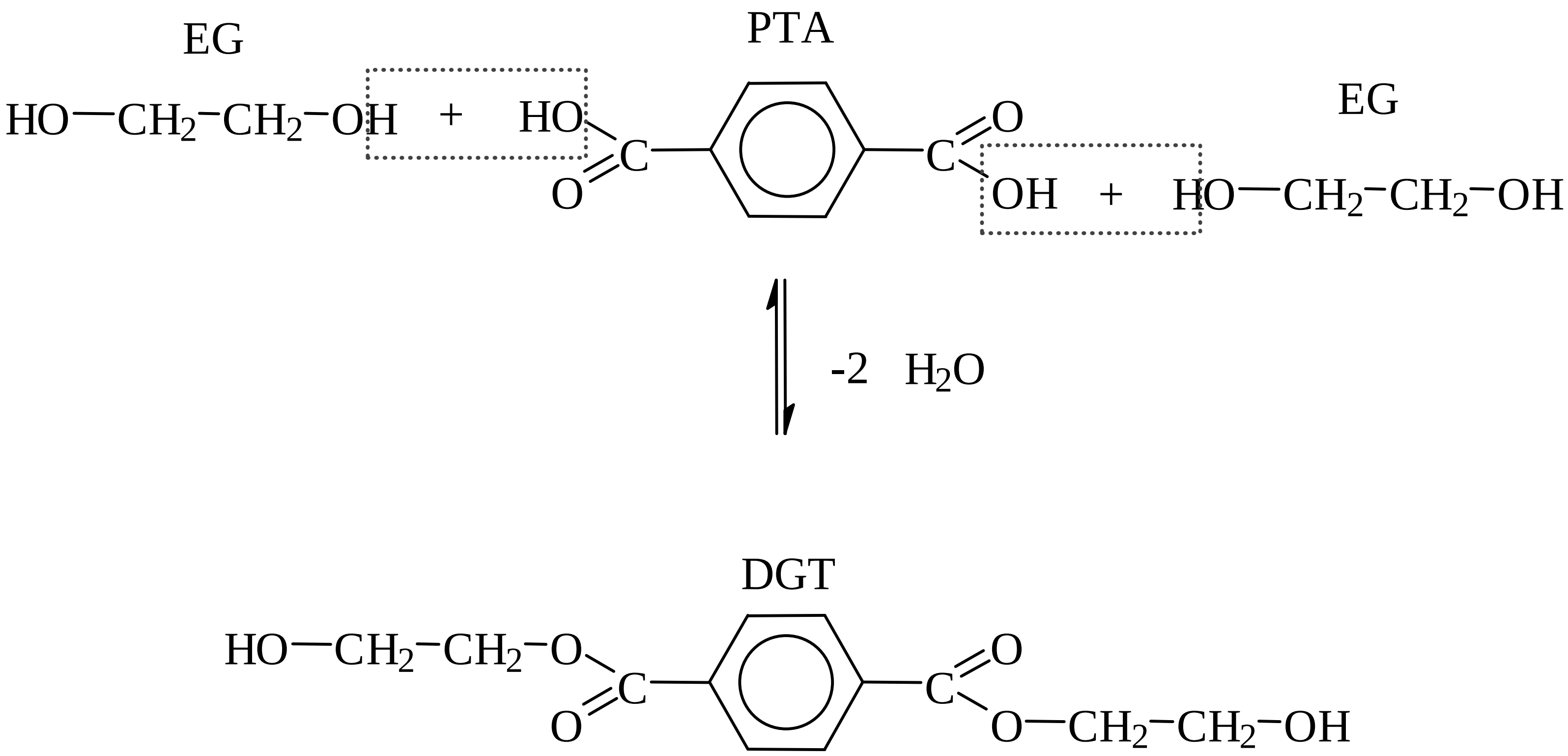
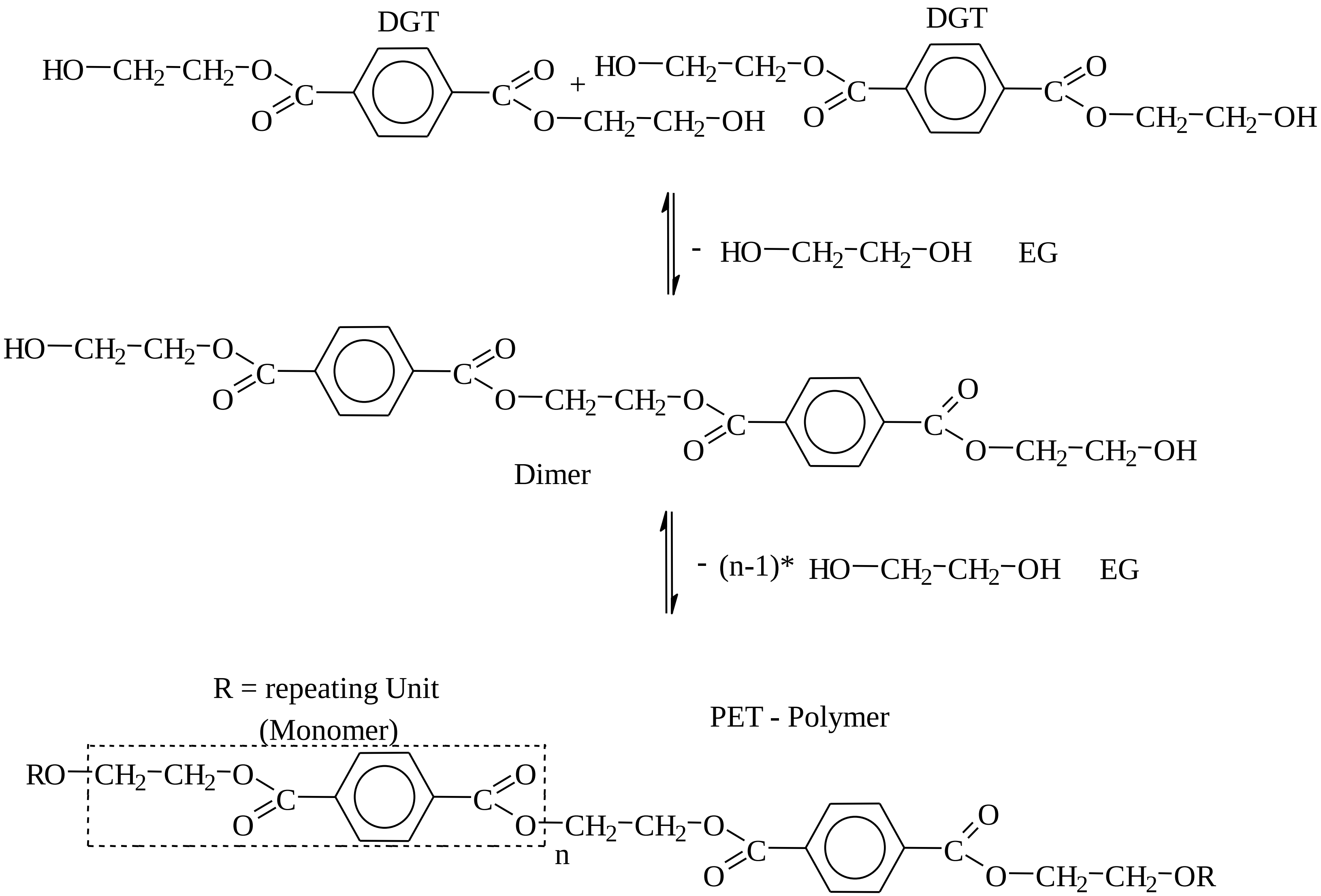
Esterification Reaction



8.1.1. Main Reactions

Polycondensation Reaction



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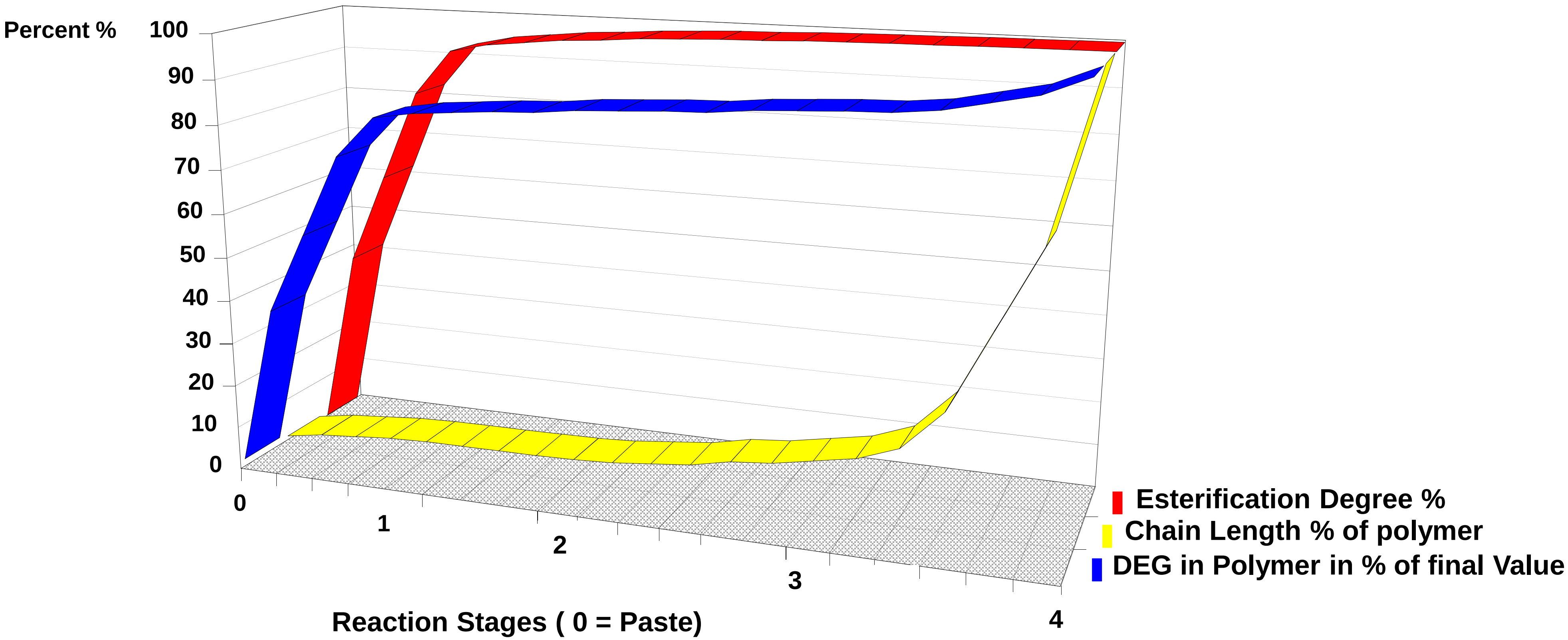
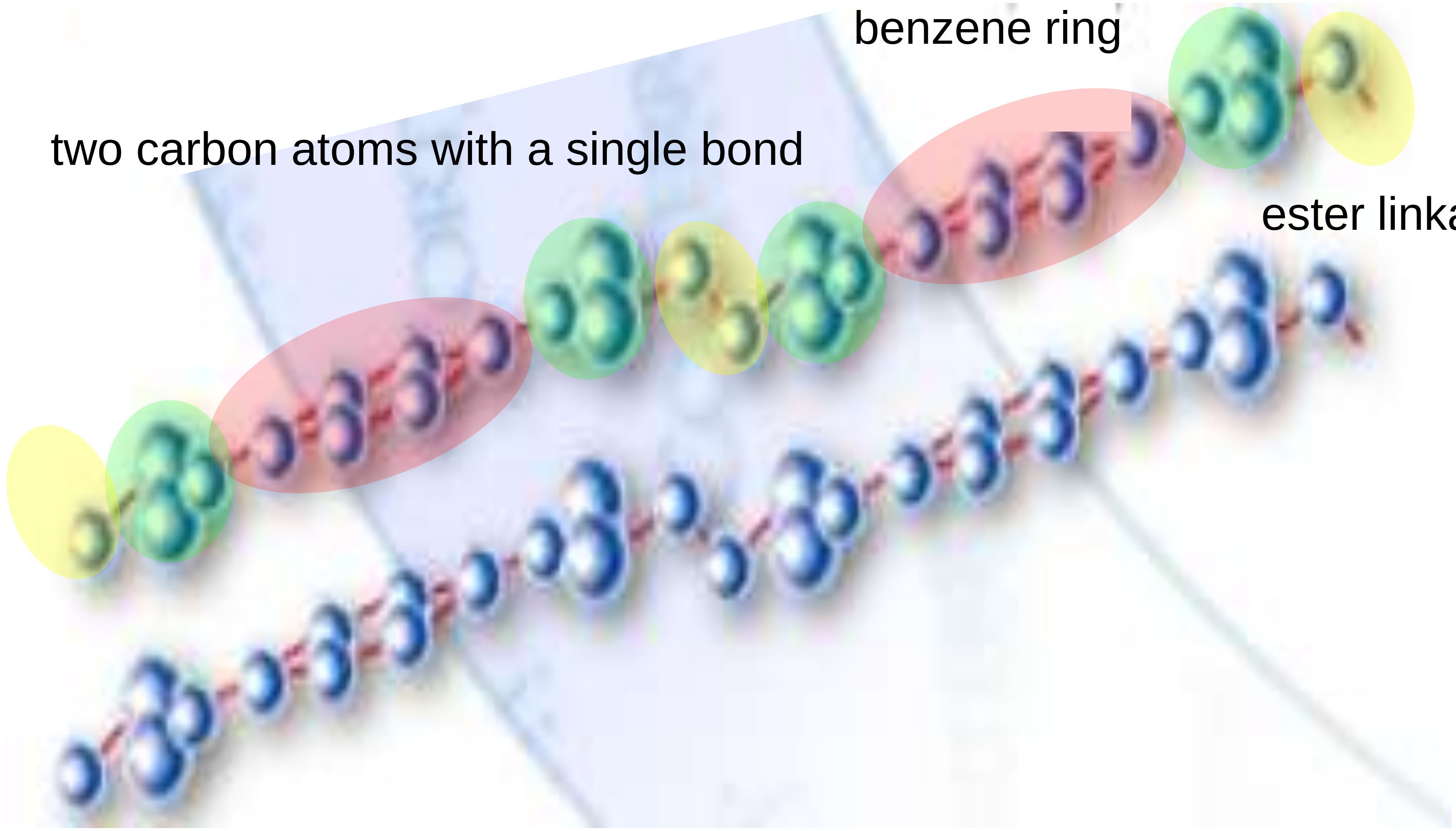
Main Physical Process Values
Continuous PET- Process using PTA/EG



Molecular Structure of PET



Diethylene Glycol (DEG) formation

EG + EG

$$HO-CH_2-CH_2-OH + HO-CH_2-CH_2-OH$$

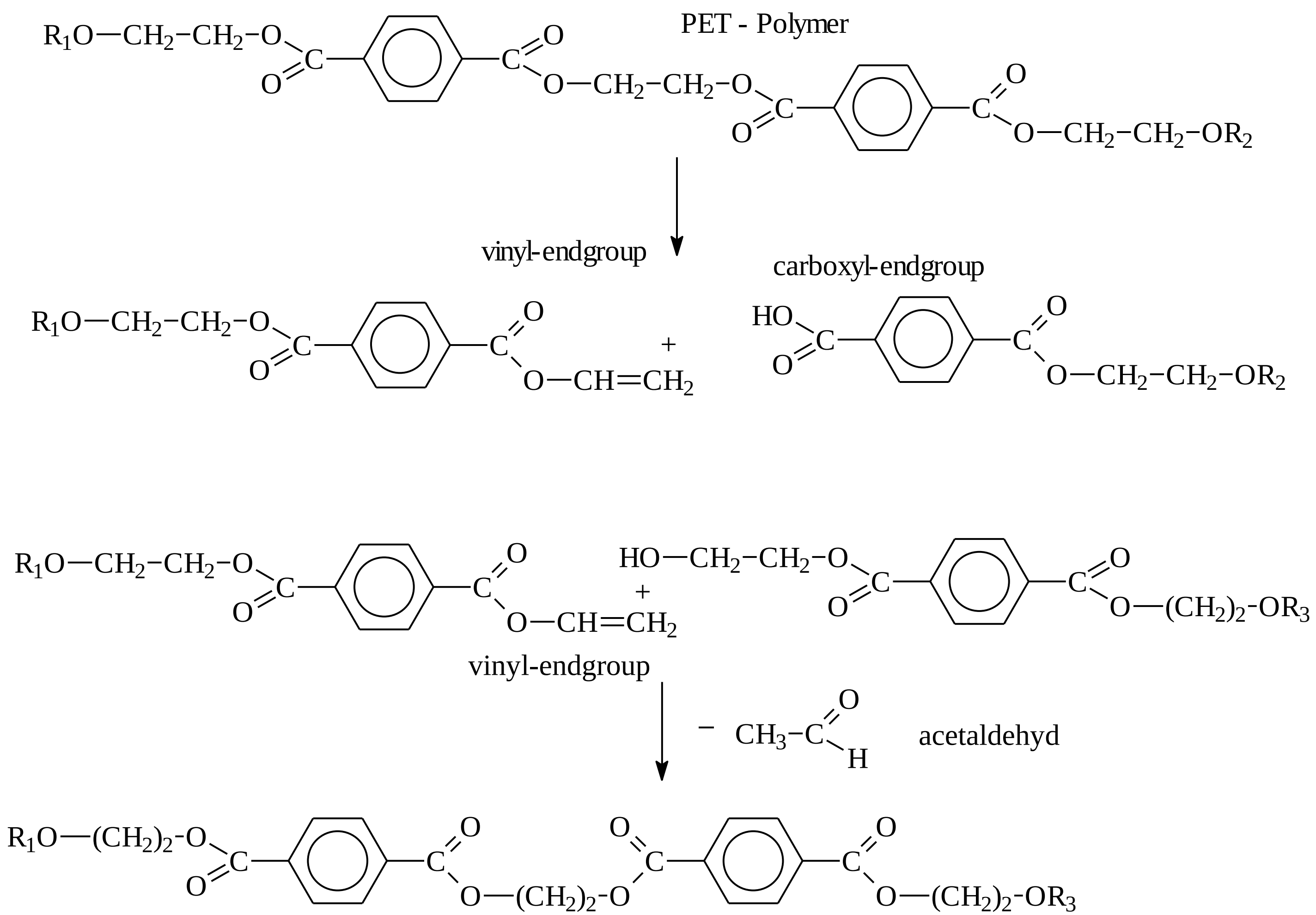
$$\rightleftharpoons$$

DEG

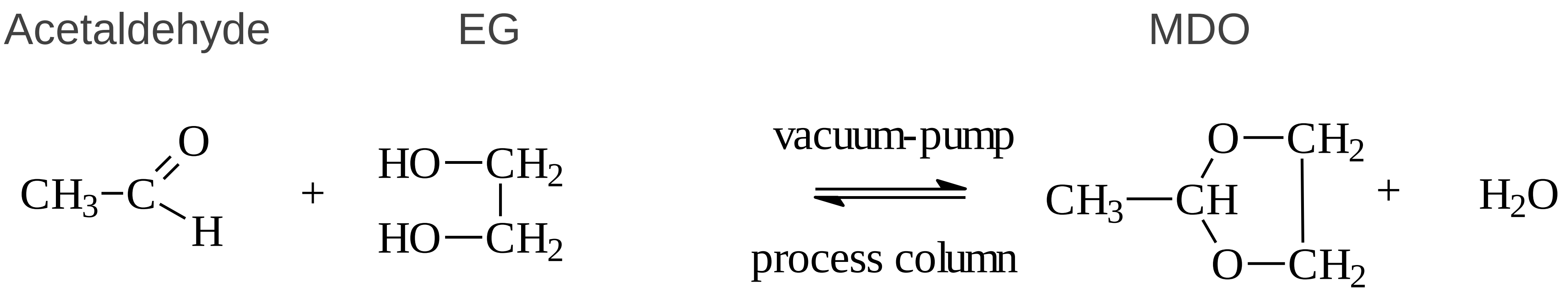
$$HO-CH_2-CH_2-O-CH_2-CH_2-OH \quad + \quad H_2O$$

8.1.2. Side Reactions

Thermal degradation



Methyldioxolane (MDO) generation



- MDO is stable against alkaline solutions
- MDO hydrolyses in presence of diluted acids to acetaldehyde and EG

8.1.3. Decomposition by Maltreatment

Zimmer

- **PET in melt phase is an organic macromolecule and sensitive against thermal stress.**
  - Thermal stress is to be defined as condition of high temperature under extended residence time.

degradation can break down PET to carbon.

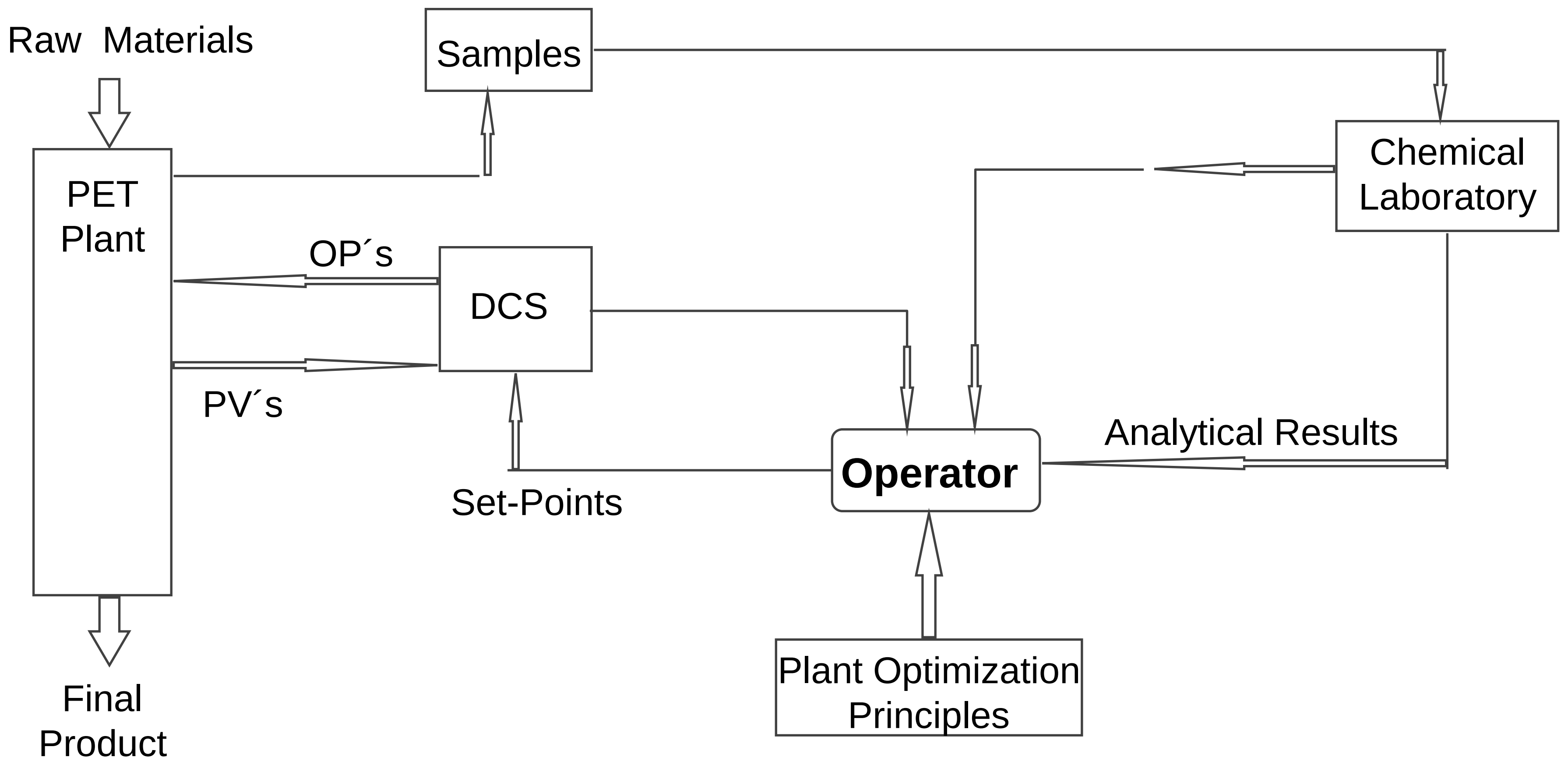
- **PET in melt form is very sensitive to oxygen.**
  - Oxygen drastically supports the PET degradation and formation of carbon.
  - Therefore all product carrying reactors and pipes need to be leak tight, specially the vacuum reactors and systems.

Extensive leak tests are essential, specially during Plant start-up preparation.

Leak tests need to be repeated on scheduled basis during production.

Zimmer

8.2.1. Quality control:



8.2.2. Quality Values

Zimmer

QUALITTY VALUES	PASTE	EF1	EF2	PP	DRR chips
PTA-content [w%]	65-75	- -	-		-
IPA-content [w%]					0-2
AN [mgKOH/g]	450-490	30-50	10-25	2-5	1-2
COOH endgr [mmol/kg]	7500-8500	530-890	170-450	35-90	18-50
SN [mgKOH/g]	450-490	500-600	510-600	560-580	560-585
Conversion [%]	-	89-90	95-98	99-99,5	99,6-99,6
Free EG [wt%]	25-35	0,1-0,3	0,1-0,3	-	--
Free water [wt%]	0-1,0	0-0,2	0-0,2	--	0,01-0,4
Melting point [°C]					242-260
DEG [wt%]	0-0,2	0,5-1,3	0,7-1,3	0,7-1,5	0,8-1,5
IV [dl/g]				0,15-0,25	0,55-0,66
Antimony [ppm]	120-200			150-230	150-230
Cobalt [ppm]	0-20			0-20	0-20
Phosphor [ppm]			0-30	0-30	0-30
Blue toner [ppm]					0,3-1,5
AA [ppm]					30-80
Chips [wt g/100chip]					1,3 -3
Colour L					75-100
a					-3- 0
b					-5- +6

Zimmer

8.3.2.1 Acid number:

AN in mg KOH / g sample

- measured in chemical laboratory only
- represents the non-esterified acid end groups of PTA (COOH)

Can be expressed as COOH end groups [mmol / kg] :

$$COOH := AN \cdot \frac{1000}{M_{KOH}}$$

Zimmer

8.3.2.2 Saponification number

SN in mg KOH / g sample

- **Measured in chemical laboratory only.**
  - Represents all acid end groups of the PTA, independent if those end groups are esterified or not;
  - therefore the SN represents the concentration of the PTA in the reaction mixture.
  - Mainly used in combination with AN to calculate the esterification degree :

$$e := \frac{SN - AN}{SN}$$

8.3.2.3 Intrinsic Viscosity:

IV **indicates the chain length of PET**

depending on a reproducible analytical method at given temperature

- **Measured in the chemical laboratory**
  - by solving of a certain amount of PET-sample in a solvent (phenol -1,2-di-chlorobenzene) and measuring the time of flow of the solution in an Ubbelohde viscosimeter.
  - Obtained value of relative viscosity is converted in IV.

- **Measured on-line in a capillary viscosimeter**
  - by using the differential pressure of a defined capillary at defined flow.
  - Calculates out of the differential pressure the dynamic viscosity.
  - Converts automatically the dynamic-viscosity into IV by using the measured melt temperature and empirical conversion formula.

8.3.2.3 Intrinsic Viscosity:

- **Analytical background**

  - prepare PET solution of defined concentration c (0.5 – 0,65 g/ 100 ml (10 dl))

  - determine time of flow of PET solution t and time of flow of pure solvent t_0

- **Mathematical background**

  The viscosity of the PET solution and of the pure solvent are proportional to the corresponding time of flows, so that the relative viscosity can be obtained as following quotient:

$$RV = \frac{Visc._{\text{PET solution}}}{Visc._{\text{pure solvent}}} = \frac{t}{t_0}$$

The Intrinsic viscosity is defined as the limiting value of the ratio of the natural logarithm of the relative solution viscosity to the concentration c of the polymer in the solution for c against 0.

$$IV = \lim_{c \to 0} \frac{\ln RV}{c}$$

8.3.2.3 Intrinsic Viscosity:

- **The relative viscosity is linked with the intrinsic viscosity via Billmeyer's equation**

$$IV = \frac{1}{4} \cdot \frac{RV-1}{c} + \frac{3}{4} \cdot \frac{(\ln RV)}{c} \quad [dl / g]$$

(J. Polym. Sci. 4, 83-86 (1949))

- **The IV represents the chain molecular weight of the macromolecule and can be used to calculate the chain length in further steps**

$$M_{CHAIN} = 36119.5 \times IV^{1.46}$$

The average molecular weight of a final PET is approx. 19 000 kg / kmol with an chain length of approx. 95 to 100 (IV approx. 0.64 dl/g)

8.3.2. Main important lab values

8.3.2. Main important lab values

Zimmer

8.3.2.4 Melting Point of PET

Mp in °C

- **Measured in the Chem. Lab. only (DSC- Method)**
- **Depending mainly on the co-monomer concentration in the PET**
  - the main co-monomers are DEG and IPA

Melting point = 261 - 3,06 * IPA [wt.-%] - 4,2 * DEG [wt.-%] in °C

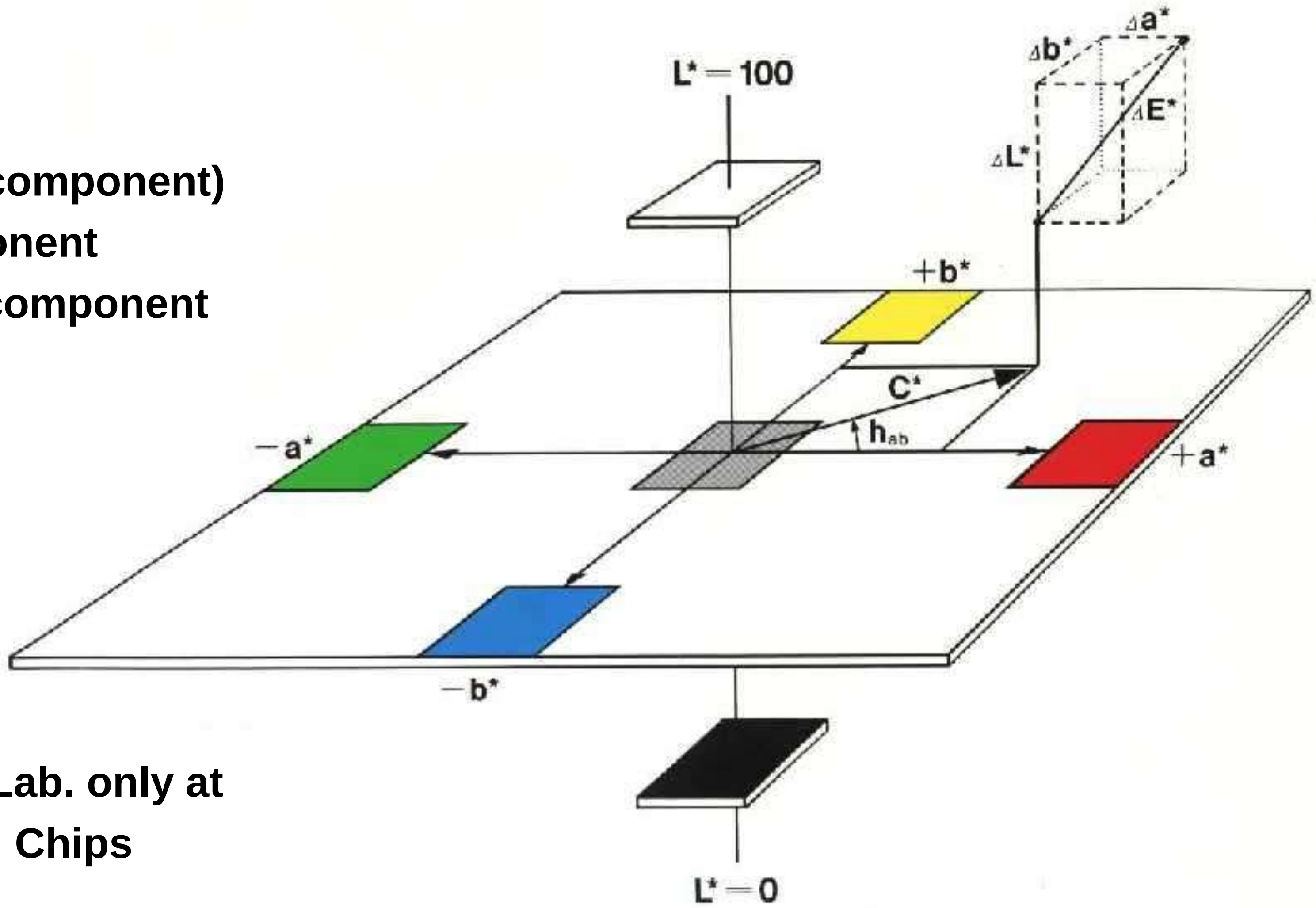
- **For bottle grade production a low Melting Point is essential in order to minimize process temperatures and decomposition of PET during bottle making.**

8.3.2. Main important lab values

Zimmer

8.3.2.5 Colour of PET

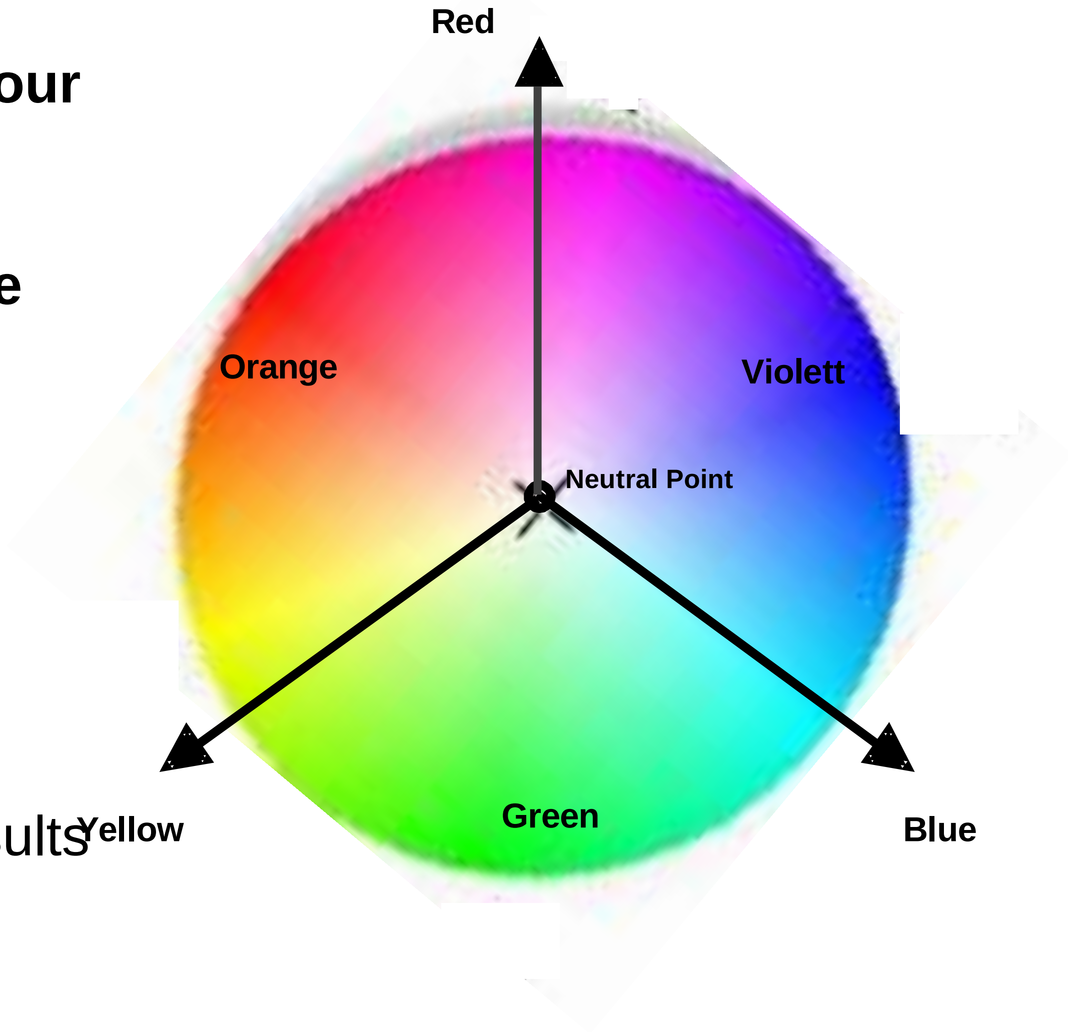
L*	**brightness (grey component)**
a*	**red - green component**
b*	**the yellow - blue component**



- **Measured in the Chem. Lab. only at crystallized and ground Chips**
  - main important value is the b* value

8.3.2.5 Colour adjustment (simplified graph)

- **PET as polymer has a typical Colour with the tendency to yellow**
- **Bottle Grade PET is tuned by Blue Toner (Co and Organic Blue Dye)**
  - Cobalt contains a blue and red component
  - Blue Toner contains a blue component only
  - Additive colour compensation results in increase of grey Value



8.3.3. Sampling

- **Samples are used to check the quality of raw materials (PTA, EG),**
  the product and process performance in the process stages, as well as
  the quality of the final product (chips)

- **Analysis results provide information about product quality, process parameter changes and malfunctions**

- **Sample collection**
  - Routine sampling according to a regular procedure (analysis plan)
  - Sampling during ‚unusual situations‘
  - Clean sample container or bag with clear labeling (sample number, date, etc.)

- **Analysis plan**
  - Type of Determination
  - Analytical Method
  - Sample point (Place of Sampling)
  - Number of Tests

8.3.3. Sampling

Zimmer

8.3.3.1 Special cases of sample collection

- **Paste sample (from paste preparation vessel, once per shift)**
  - must be homogenized by sample shaker before analysis

- **Esterification product (after ES-product pump, once per shift)**
  - Always wear safety clothes (protective clothing, special safety gloves, face shield).
  - Follow the safety rules for the handling of hot product.
  - Use only clean sample containers


Caution

Burn Hazard!

The product comes out hot and under pressure!

If the molten product comes in contact with the skin, it will stick to the skin and clothing and it will burn into the skin during solidification.

8.3.3. Sampling

Zimmer

8.3.3.1 Sampling schedule

SAMPLING SCHEDULE

Time	Type / place of sampling	Type of determination
09:00 / 17:00 / 01:00	**Paste preparation** SP AB30-A-12P01/02	cTPA, cEG, (cH2O)
07:30 / 15:30 / 23:00	**Esterification I product** SP AB40-A-11R01	AN, SN, Conv., cEG, cDEG
07:30 / 15:30 / 23:00	**Esterification II product** SP AB40-A-21R01	AN, SN, Conv., cEG, cDEG
07:30/ 15:30/ 23:00	**Precondensation product** SP AB50-A-86P01	IV, SN, -COOH, Conv., cEG, cDEG
07:30 / 15:30 / 23:00	**PETP chips** after granulate dryer	IV, -COOH, Colour, Ash, cH20, Melting point, DEG, Acetaldehyd, haze value,

8.3.3. Sampling

8.3.3.1 Sampling schedule

Time	Type / place of sampling	Type of determination
10:00 1x per week	**Vessels** AB40-A-60 reflux vessel AB40-A-41P03/04 bottom column AB50-A-62 immersion vessel AB60-A-50 immersion vessel AB60-A-63 immersion vessel AB60-A-63 collecting vessel AB60-A-63 eg-evaporator AB11-A-12 seg collecting ve.	cEG, cH2O, (c oligomers)
each batch	**Catalyst batch preparation** SP AB15-A-22 V01	conc. Sb; conc. Co
each batch	**Additive batch preparation** SP AB17-A-21V01	conc. P

Conclusion

	ZIMMER POLYESTER PROCESS OVERALL VIEW						
PARAMETER	UNIT	PASTE MIXER	ES 1	ES 2	PP	DRR	Information
TIME	min	190	220	85	75	140	
TEMPERATURE	°C	45-55	259	265	270	278	
PRESSURE	mbar (a)	ATM	1200...1500	1070...1115	20...30	0,9...1,5	
summary MOLRATIO	EG / PTA	1,05......1,15	1,65...1,69	1,8...1,83			1,8...1,9
ES-DEGREE	%	_	90...93	96,5...97,5	99,5...99,7	99.8	
CHAINLENGTH	n		4	5	16	100	
POLYCONDENS.DEGREE	%		75...76	79...80	93,8...94	99.8	
INTRINSIC VISCOSITY			0.093	0.097	0,18...0,27	0,6...0,66	
DYN.VISCOSITY	Pas	4.....10	0.032	0.033	3.49	350...400	=f(T,s)
MOL WEIGHT					3100	18000...19500	M = n * 192,17 + 62,1 kg/kmol
COOH	meq/g	12011	1000...800	350	80...40	28	=AN * 17,82
c H2O	wt%	0,05.....0,1	0.06	0.05	8 x10	0	
c EG	wt%		0.2	0.04	0.01	0	
c DEG	wt%		0,6...0,7	0,7...0,8	0.85	0,8...0,9	without additional DEG