

# PET Poly & SSP

**Zimmer**



Proven Way for successful Production Units  
by Stefan Deiß  
Head of Technology Management Polymers



Safeguarded way for  
successful Clients

1. State of the Art Polycondensation Unit
2. Newest Solid State Polycondensation Technology
3. Total Plant Optimization
4. Benefits for our Client



## 1. State of the Art Polycondensation Unit

### Profitability of plants based on:

#### ▶ **low conversion cost of product**

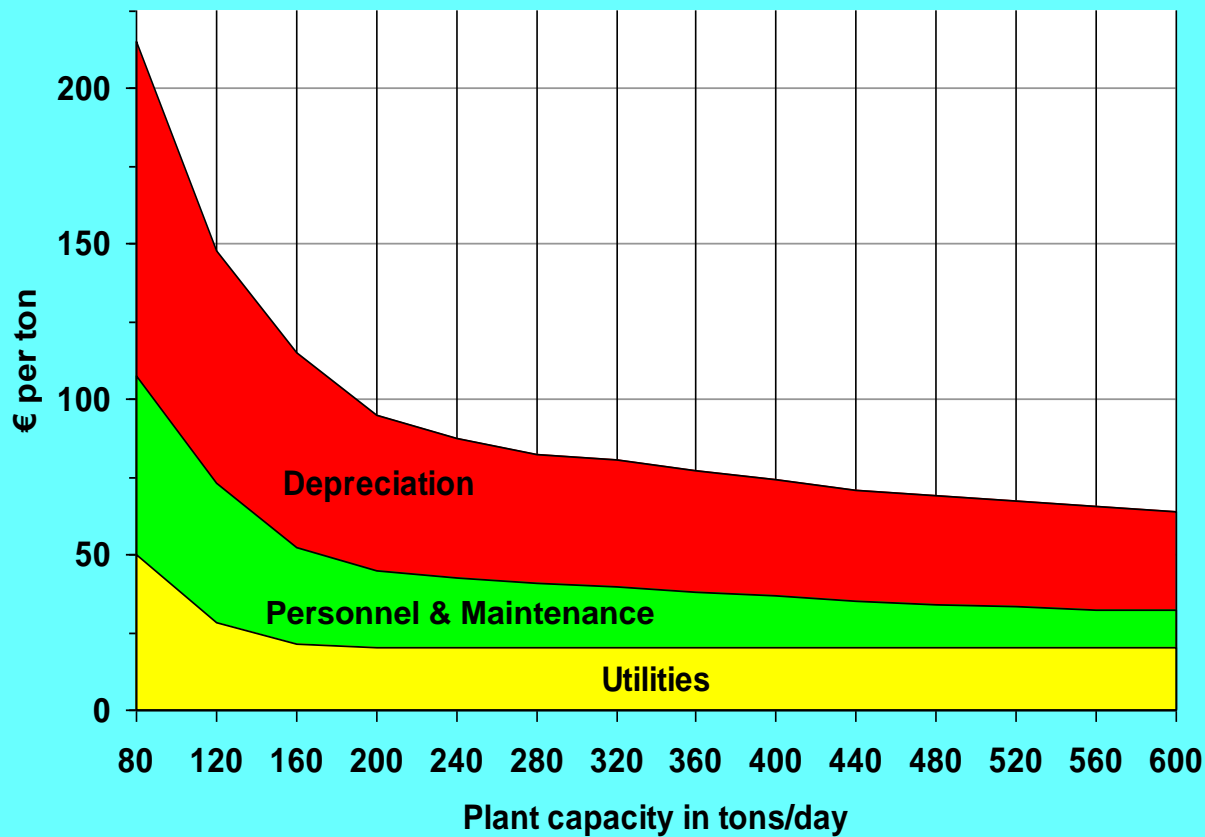
- investment cost
- personnel and maintenance costs
- utilities cost
- plant reliability
- environmentally friendly process

#### ▶ **excellent product quality**

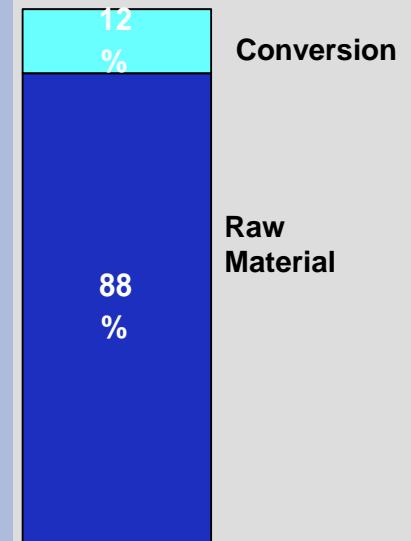
- controlled by the process (melt polycondensation and SSP)
- controlled by co-monomers
- controlled by additives

# PET Poly, low conversion cost of product

By increasing plant capacity, melt/chip conversion cost drops



Production cost (300 t/d)



## Plant Reliability

There are Zimmer customers who operate their plants up to 6 years without shut down, e.g. JCT / India.

- ▶ Due to local legal regulations inspection of equipment is ordered
  - in Germany every 5 years inside inspection of reactors
  - in Taiwan every 2 years check of safety-valves
- ▶ Mechanical maintenance cycle
  - Zimmer's recommendation: every 3 years operation, plant shut down for regular general maintenance, continuous preventive maintenance granted
  - Zimmer's clients: mainly every 4 - 6 years operation, plant shut down for regular maintenance depending on:
    - local authorities
    - plant operation
    - preventive maintenance

# PET Poly & SSP, low conversion cost of product

## On stream factor of polycondensation plant & SSP

- Required time for shut down and maintenance
  - shut down and cooling down of equipment for inspection 3 days
  - inspection of equipment, exchange of mechanical seals 1 day
  - heating-up and leak check of plant 2 days
  - restart of plant 1 day
  - ---

 **Total 7 days**

**Based on a shut down period of 7 days every 3 years, the yearly operation time is calculated to 363 days.**

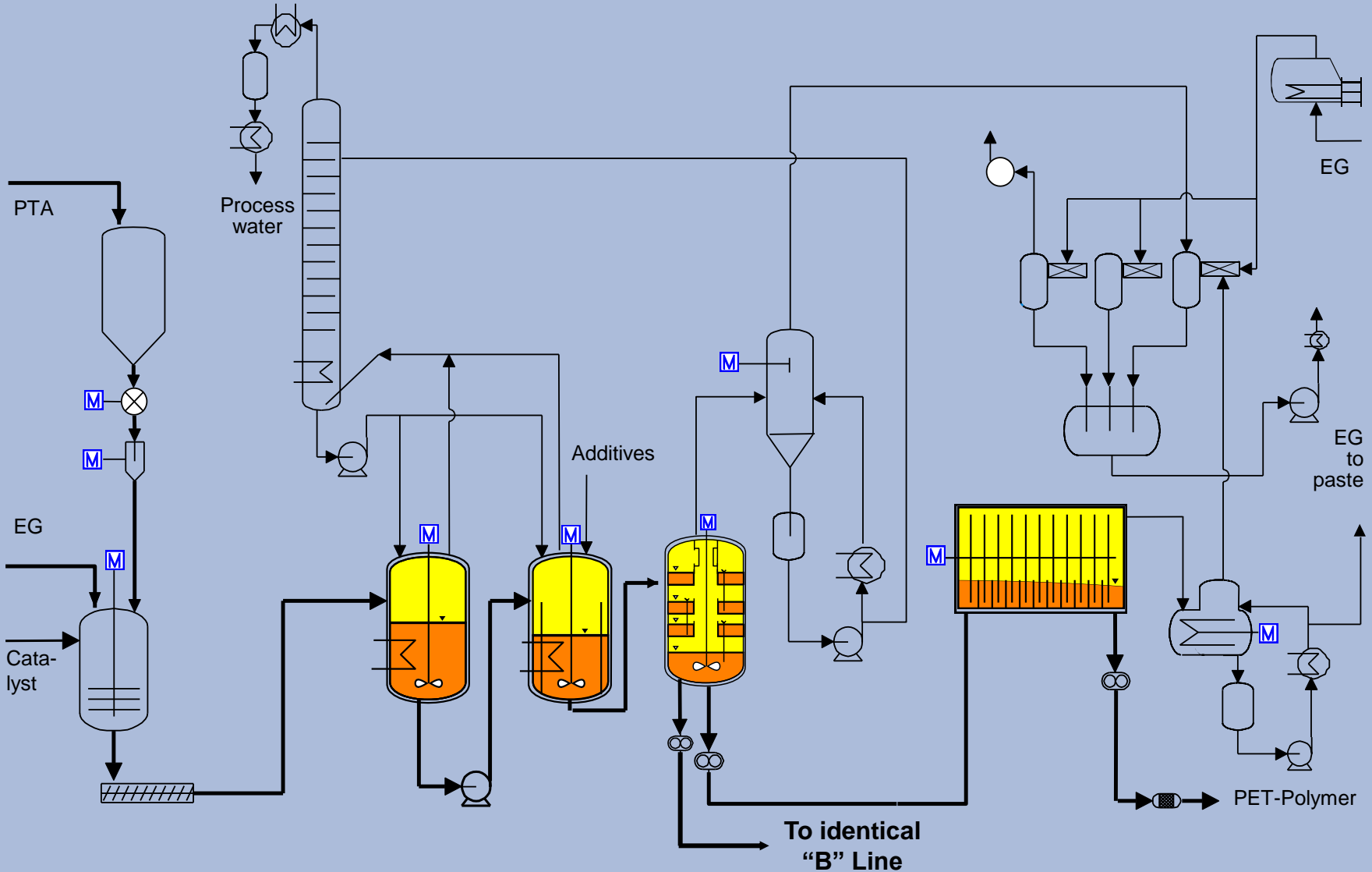
**363 days operation per year → On stream factor: 99.45%**

## Environmentally friendly process

- ▶ **low energy consumption because of:**
    - low mol ratio
    - low temperature in esterification
    - EG-jet
  - ▶ **less waste water**
    - no waste water from polycondensation (refer to vacuum system)
  - ▶ **waste water is precleaned in stripper column**
  - ▶ **emission**
    - off gas is thermally treated in HTM unit
- Result:**
- efficient and safe
  - values according to TA-Luft regulations

# PET-Poly, Economic 4-Reactor Plant concept

## Lowest conversion cost / plant concept



# PET-Poly, Economic 4-Reactor Plant concept

## Lowest conversion cost / plant concept

### ▶ Process conditions at design capacity

		Paste	E 1	E 2	PP	DRR	
MR		1.1 - 1.2	1.75				
Temperatur	°C		262	266	274	282	
Pressure	mbar		1 600	1100	15	1	
Residence time	min		225	90	75	120	∑ 510
Esterification degree	%		92	96.8	99.3	99.7	
Chainlength			4.5	6.6	22	86	
IV	dl/g		0.09	0.11	0.25	0.60	

**Confidential**

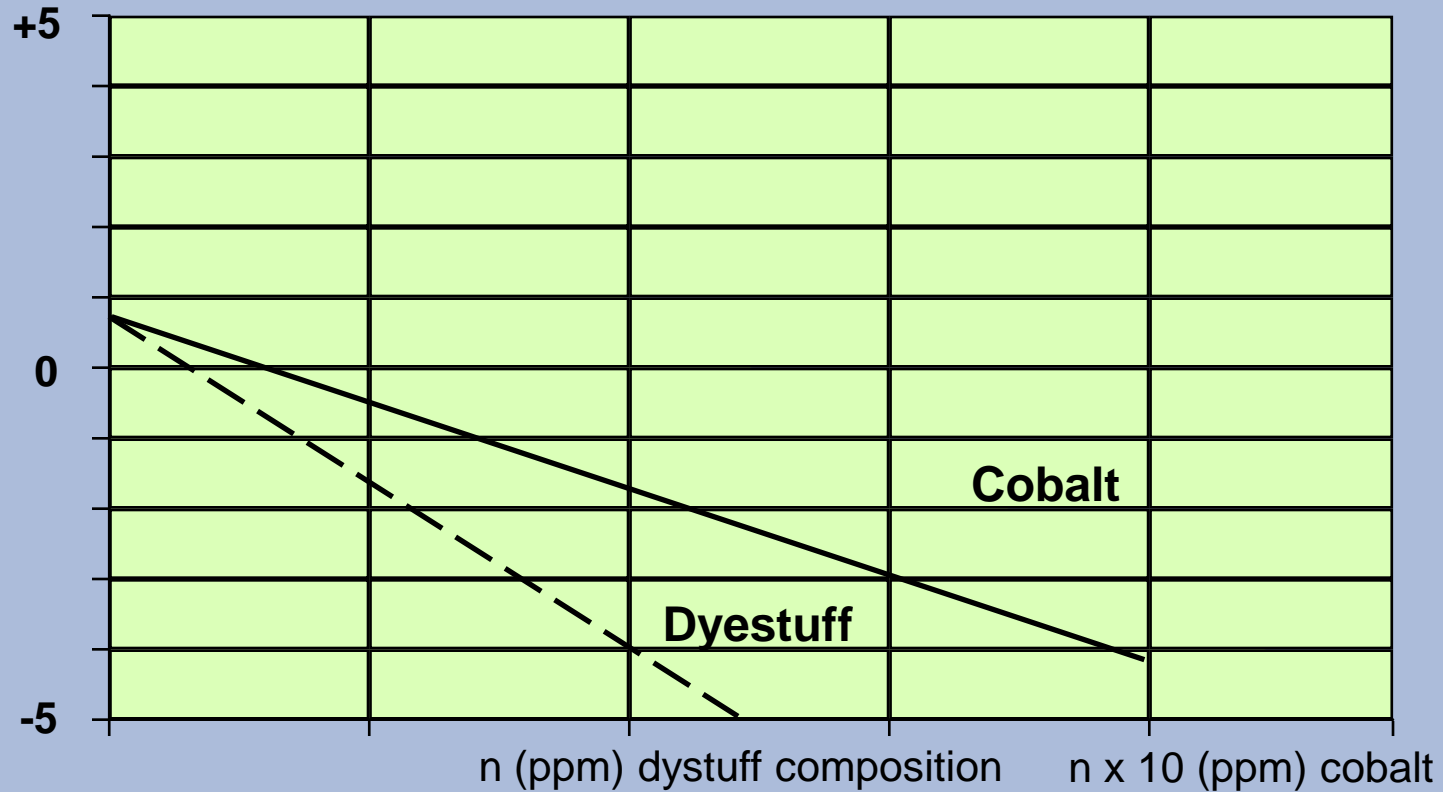
# PET Poly, low conversion cost of product

		SABIC 1200 ( USG Cutter; Air Condenser )		Bottle grade Poly & SSP					
		PTA Conveying	2x DRR Poly (AB+AH)	KB amorph	2x 600 t/d SSP	KB bottle grade	HTM	Total	
Electric Power	[kWh/t]	3,17	58,20	0,05	80,00	0,17	15,92	157,50	
Steam	[kg/t]		11,67					11,67	
Soft Water	[m <sup>3</sup> /t]		0,06				0,12	0,18	
Demin. Water	[m <sup>3</sup> /t]		0,05					0,05	
Chilled water	[m <sup>3</sup> /t]		1,00					1,00	
Cooling Water	[m <sup>3</sup> /t]	0,38	37,5		5,33		0,50	43,71	
Compressed Air	[m <sub>n</sub> <sup>3</sup> /t]			70,00	1,92	35		106,92	
Instrument Air	[m <sub>n</sub> <sup>3</sup> /t]	0,08	1,21	0,04	1,00	0,04	0,21	2,58	
Nitrogen	[m <sub>n</sub> <sup>3</sup> /t]	1,67	0,92		8,00		0,08	10,67	
Fuel Gas ( 37260 kJ/m <sup>3</sup> )	[m <sub>n</sub> <sup>3</sup> /t]		62,50		8,50			71,00	

## Bottle polymer

polymer properties	bottle quality / bottle production
<p><b>1. controlled by the process</b></p> <ul style="list-style-type: none"><li>- viscosity</li><li>- AA-content</li><li>- color</li><li>- purity<ul style="list-style-type: none"><li>• ash content</li><li>• products of thermal destruction</li></ul></li><li>- AA-reformation</li><li>- dust content</li></ul>	<p><b>mechanical strength of the bottle</b> <b>influence of taste</b> <b>brilliance</b> <b>clarity and crystallization behavior</b></p> <p><b>AA-content in pre-form</b> <b>gels and fish eyes in bottles</b></p>

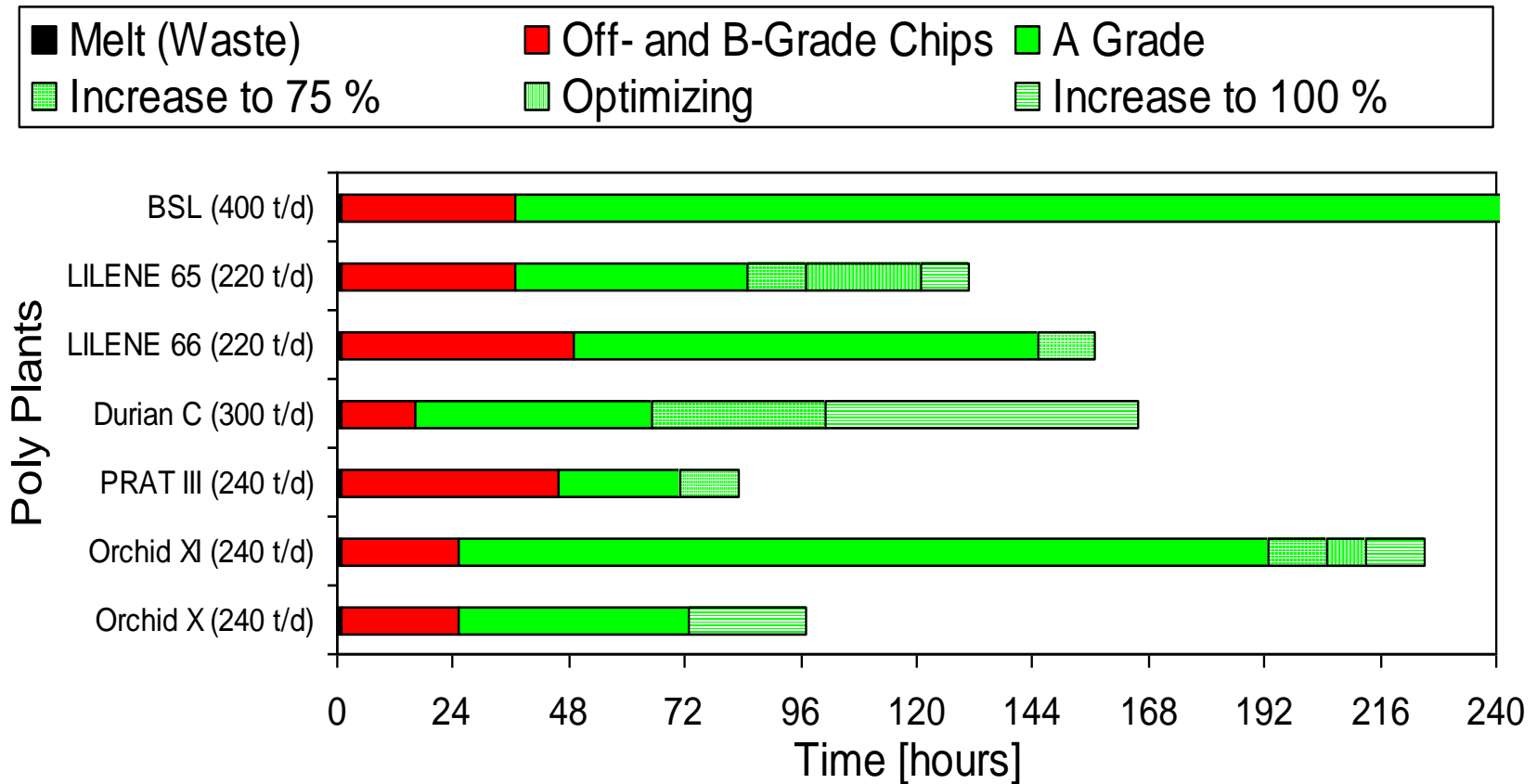
## Controlled by Additives: Cobalt and dyestuff composition on color “b” value



<b>polymer properties</b>	<b>bottle quality / bottle production</b>
<p><b>2. controlled by co-monomers</b></p> <ul style="list-style-type: none"><li>- Co-monomere content</li><li>- melt temperature</li><li>- crystallization behaviour</li><li>- glass transition point</li></ul>	<p><b>optimized cycle time in preform-manufacturing</b></p> <p><b>AA-reformation during preform production</b></p> <p><b>clarity, cycle time during production of pre-forms</b></p> <p><b>refill ability of the bottle</b></p>

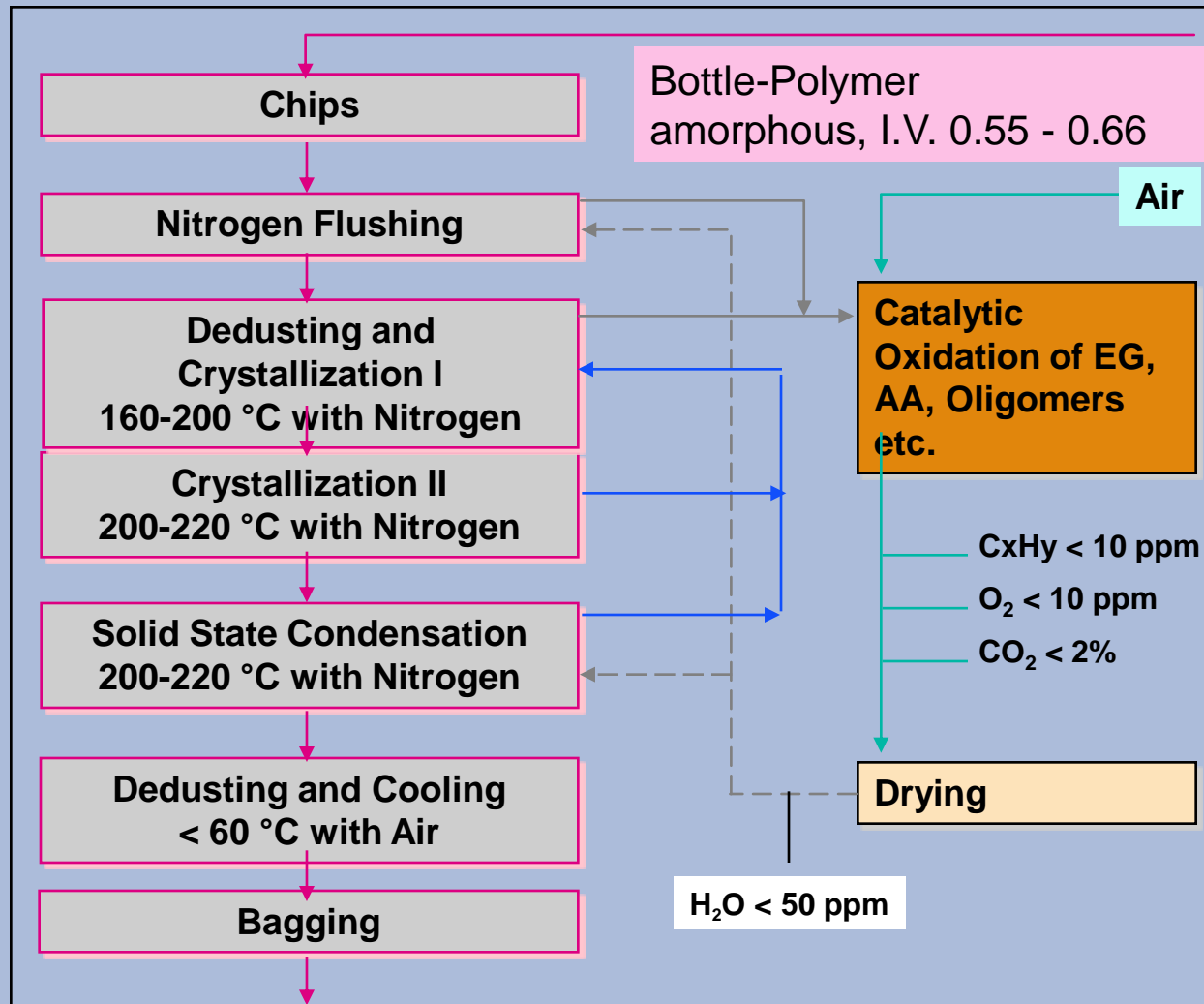
<b>polymer properties</b>	<b>bottle quality / bottle production</b>
<p><b>3. controlled by additives</b></p> <ul style="list-style-type: none"><li>- stabilizer</li> <li>- IR-absorber</li></ul>	<p><b>increased thermo-stability</b></p> <ul style="list-style-type: none"><li>• lower AA-content</li><li>• lower IV-drop</li><li>• reduced discoloration</li></ul> <p><b>better performance during stretch-blow molding</b></p> <ul style="list-style-type: none"><li>• reduced power consumption</li><li>• increased capacity</li></ul>

## QUALITY AFTER START UP

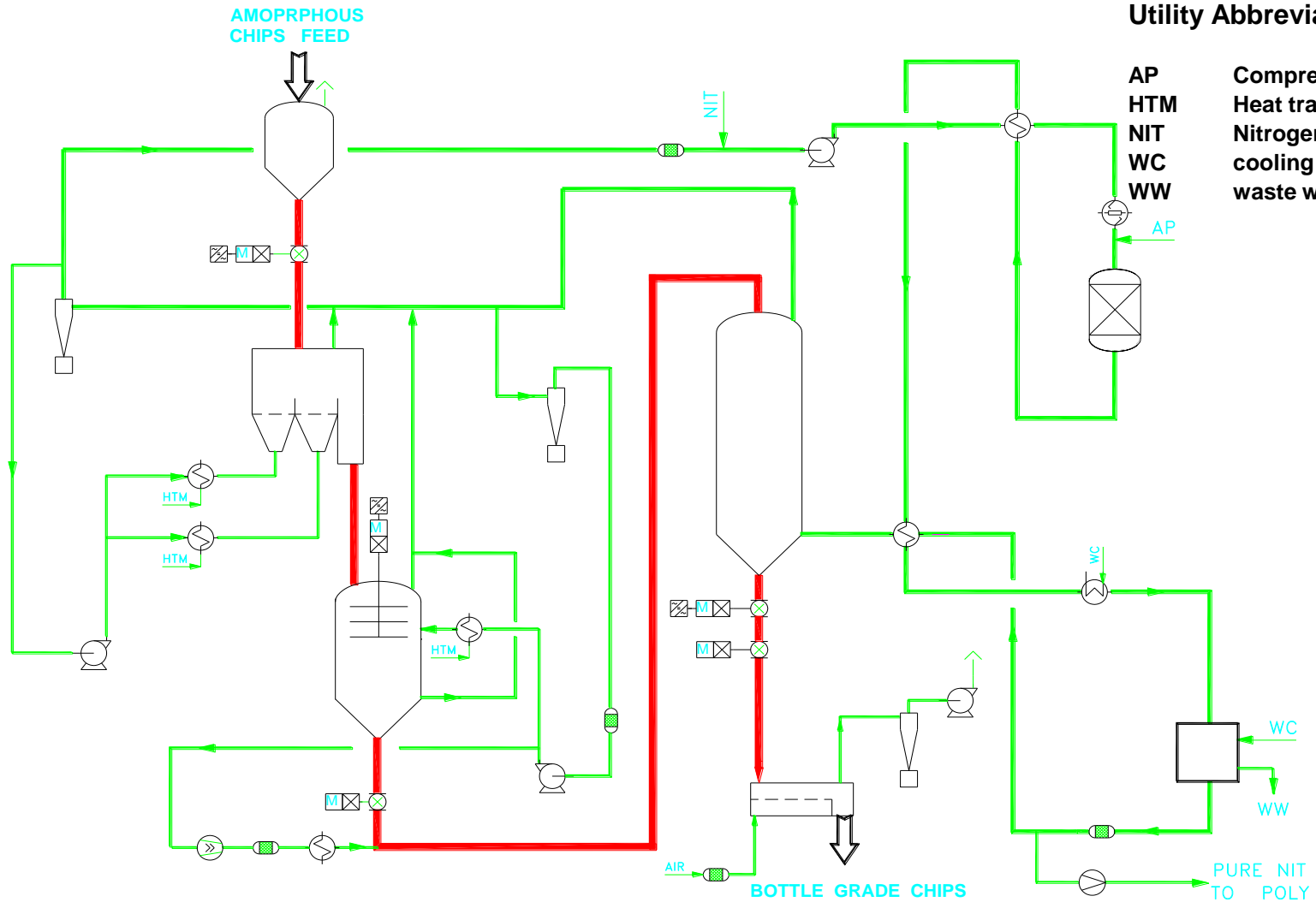


► start-up waste : approx. 10 t

## SSP Plant Technology (1)



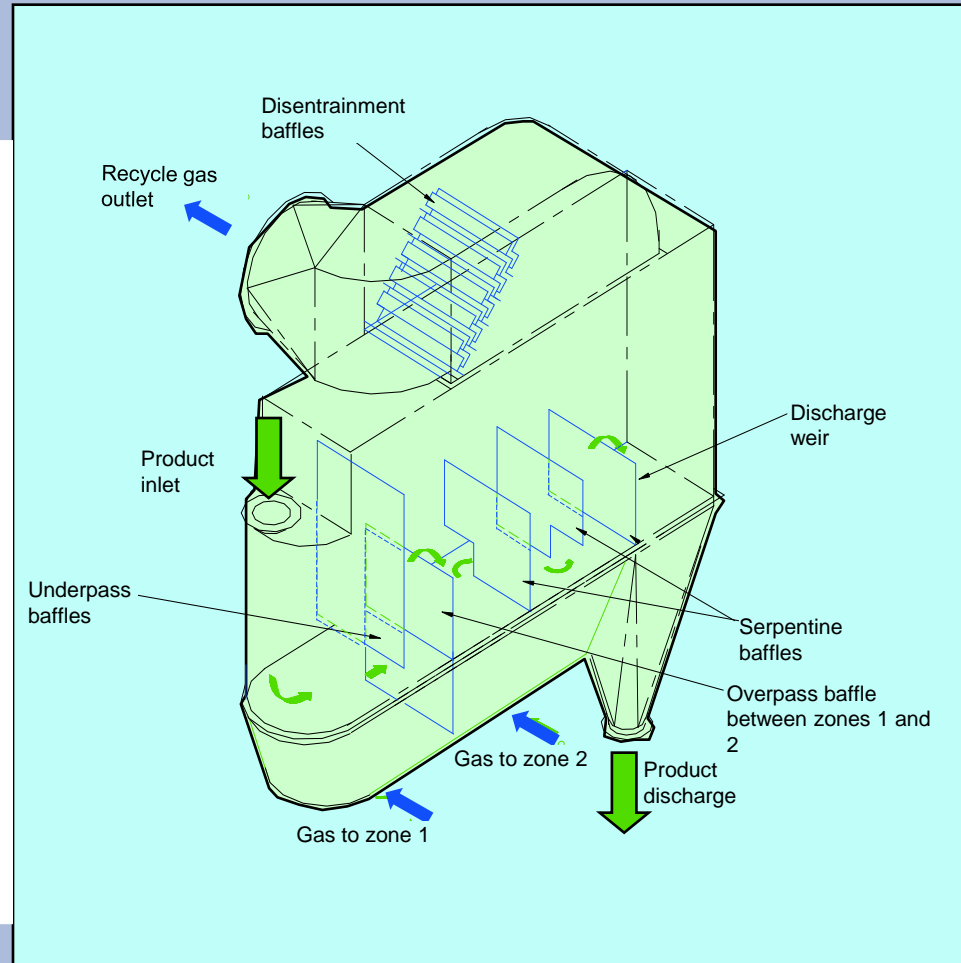
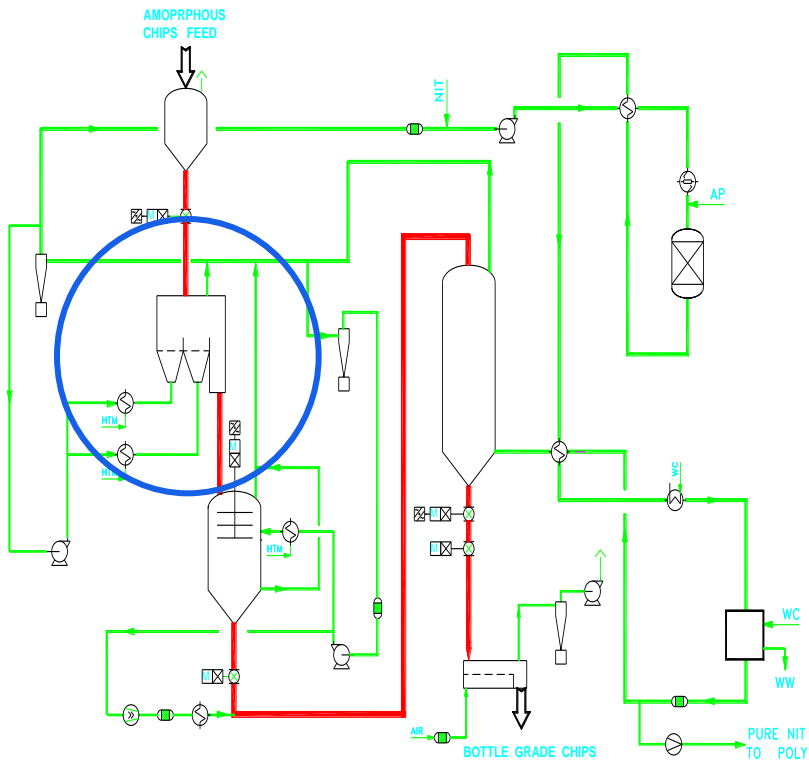
## SSP Plant Technology for Plant-capacities up to 660 t/d



### Utility Abbreviations

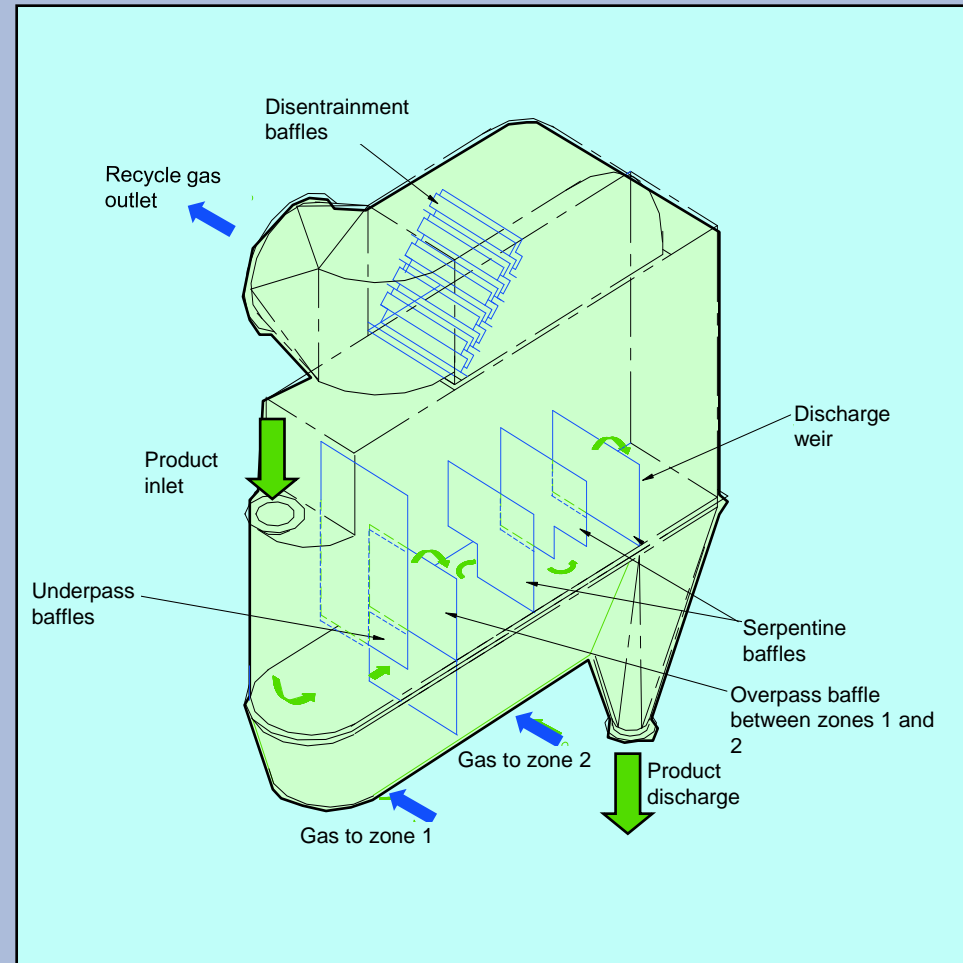
- AP Compressed air
- HTM Heat transfer medium
- NIT Nitrogen
- WC cooling water
- WW waste water

## PET – Pre-crystallizer

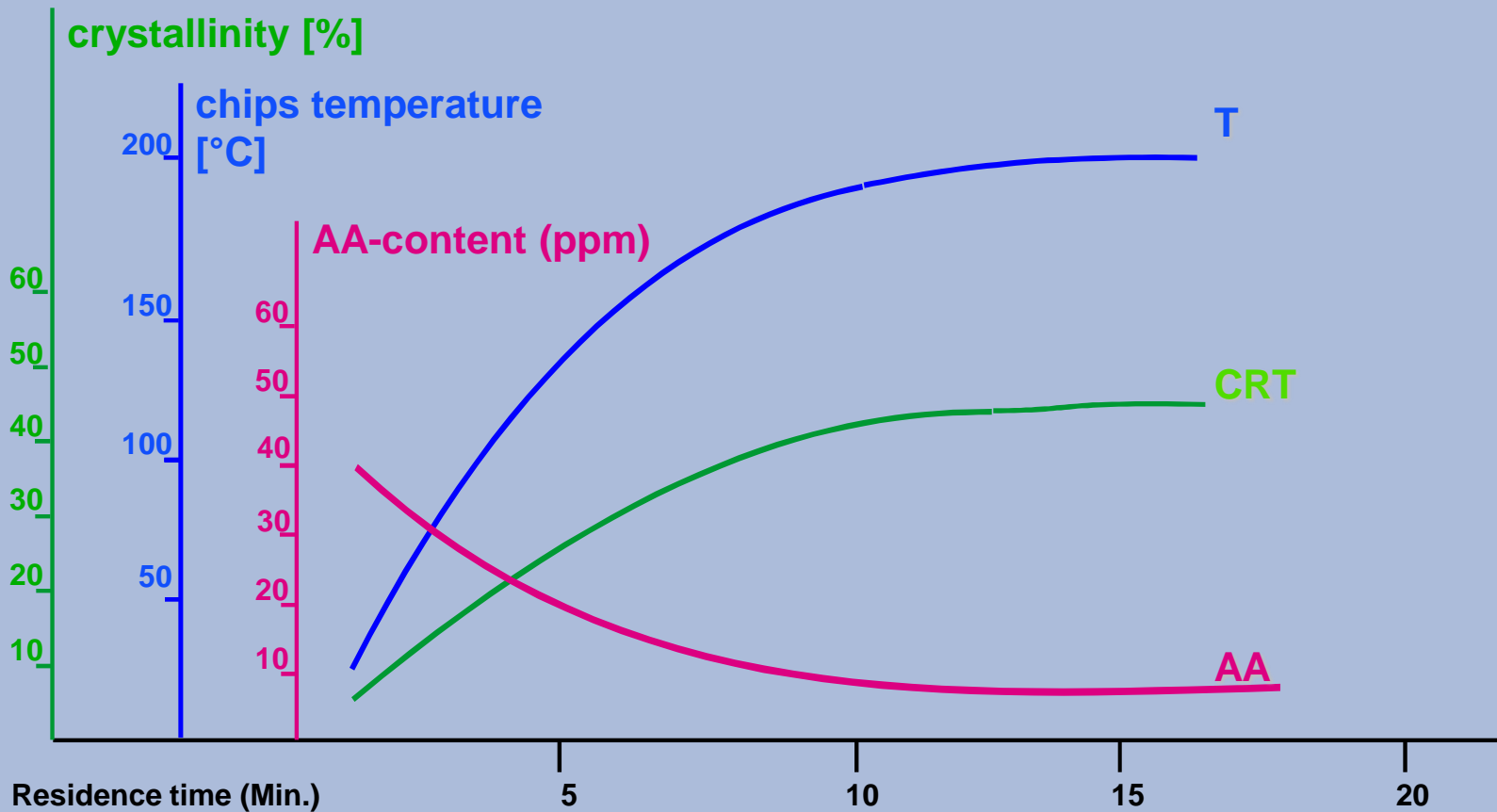


## PET – Pre-crystallizer

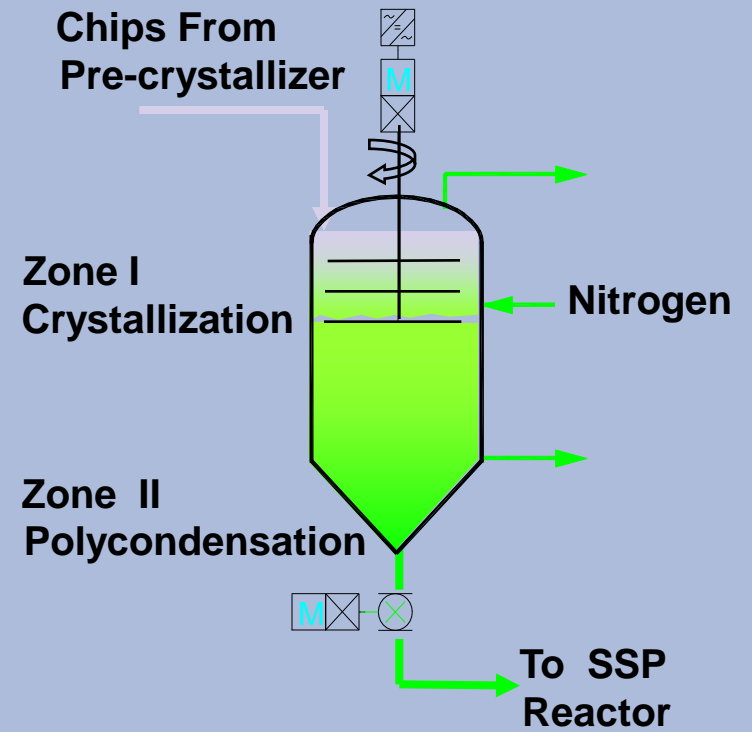
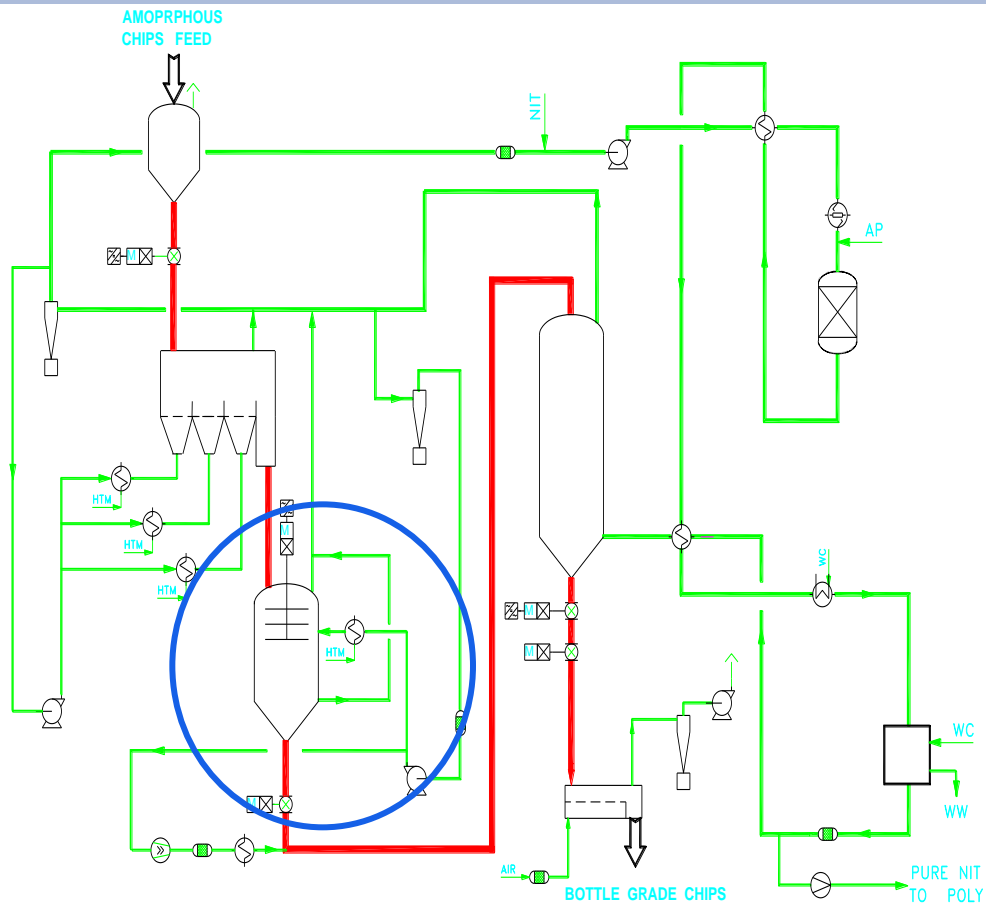
- crystallisation under nitrogen
  - ❏ oxygen free atmosphere prevents polymer degradation
  - ❏ crystallizer can be operated at a higher temperature level
  - ❏ low and constant moisture content in the nitrogen circulation system
- high nitrogen velocity through the chips bed
  - ❏ optimum de-dusting
  - ❏ high heat transfer coefficient



## PET – Pre-crystallizer

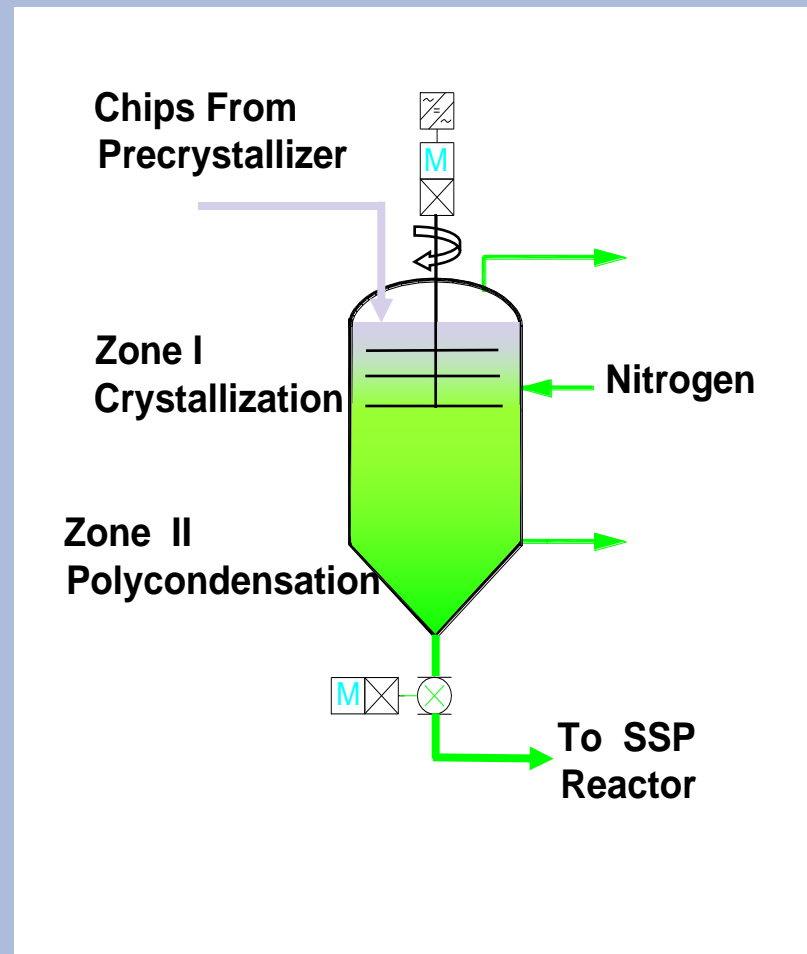


## Crystallizer

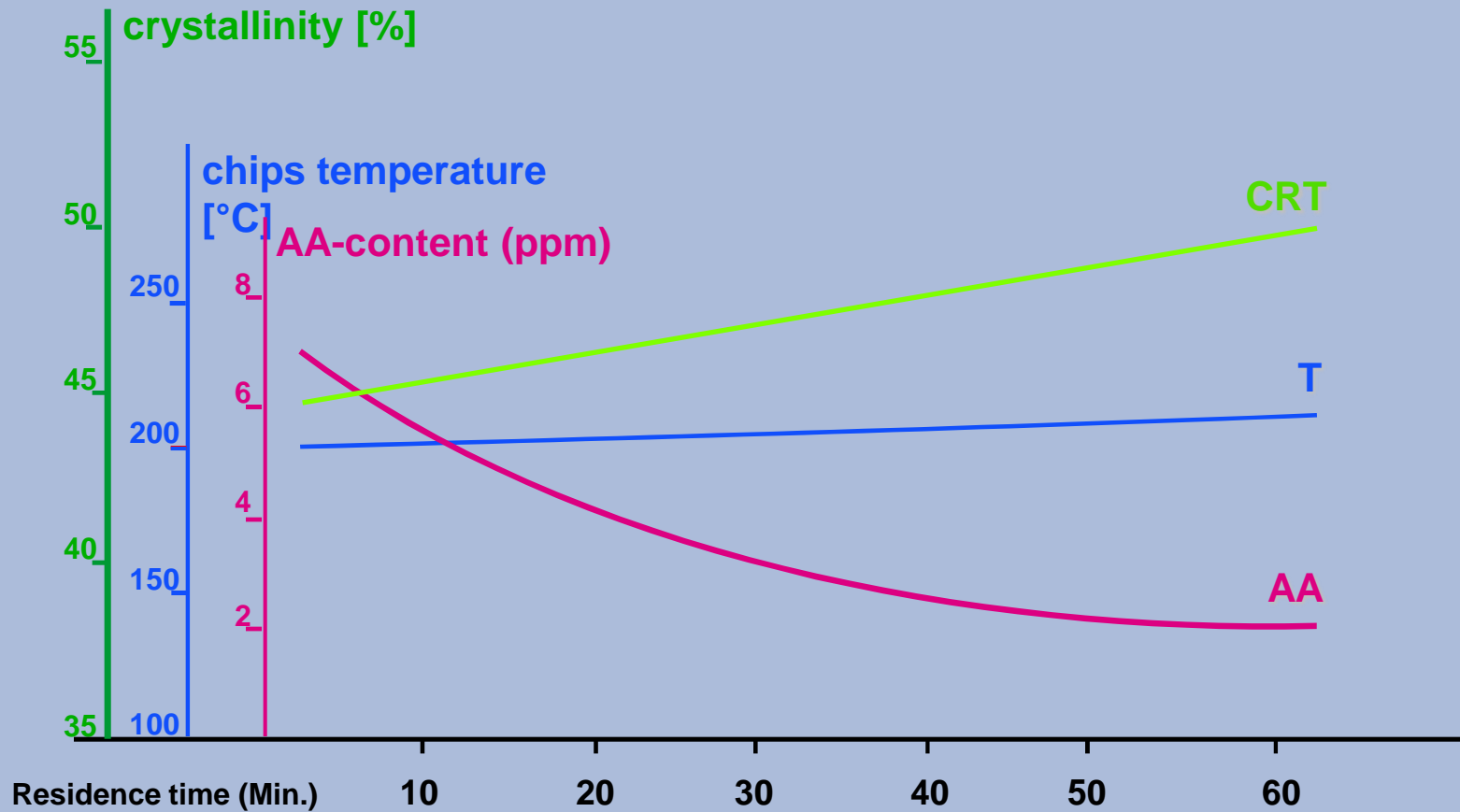


## Crystallizer

- uniform crystallization by tube crystallizer
- uniform residence time
- minimum mechanical stress
- no dead spots
- effective transport of the impurities
- limited dust generation

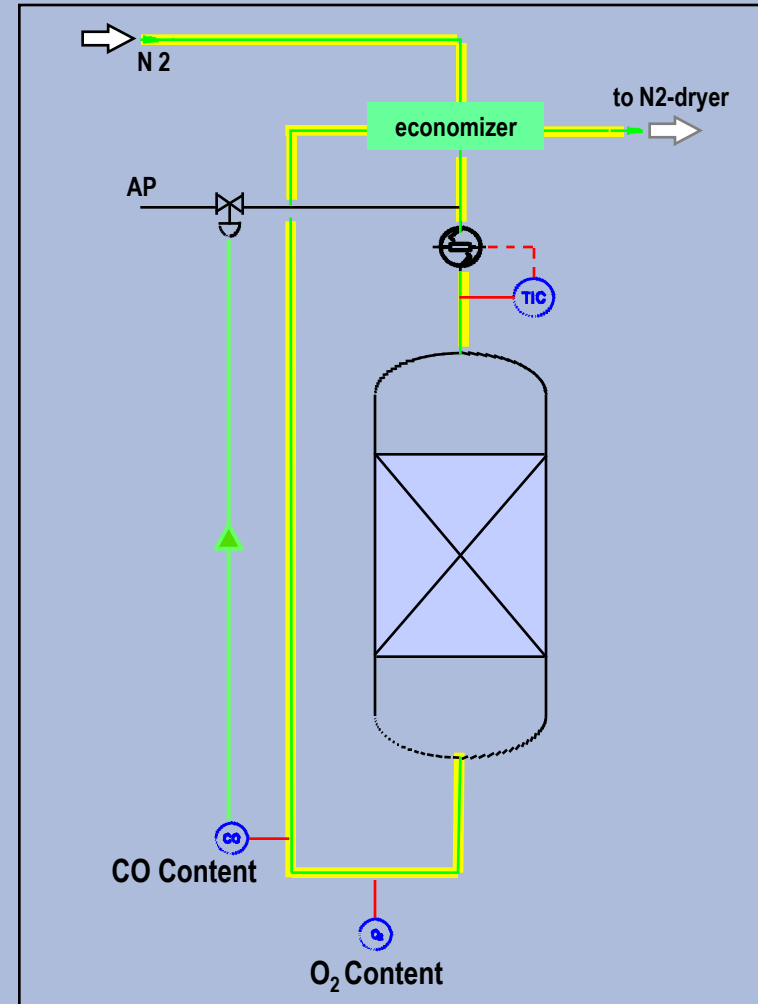


## Crystallizer



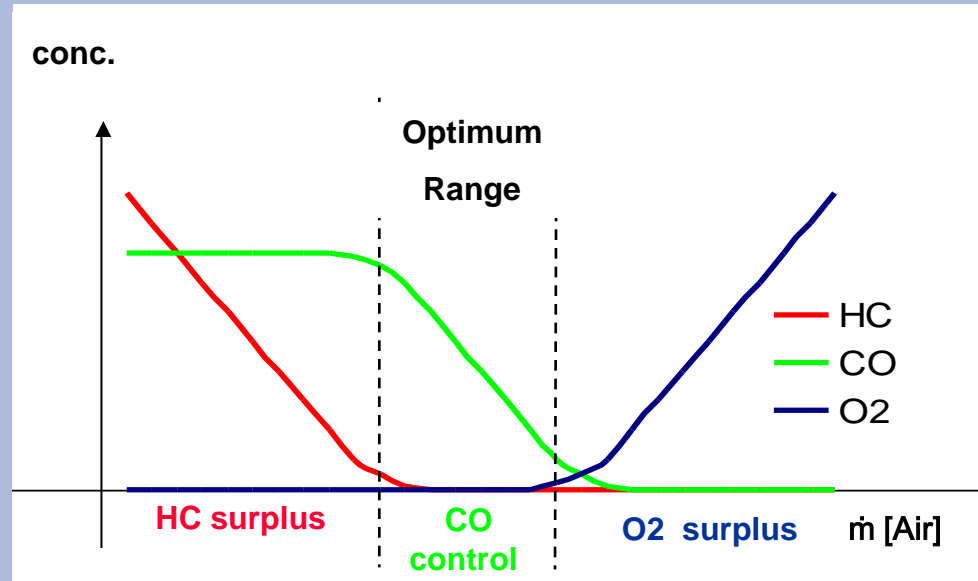
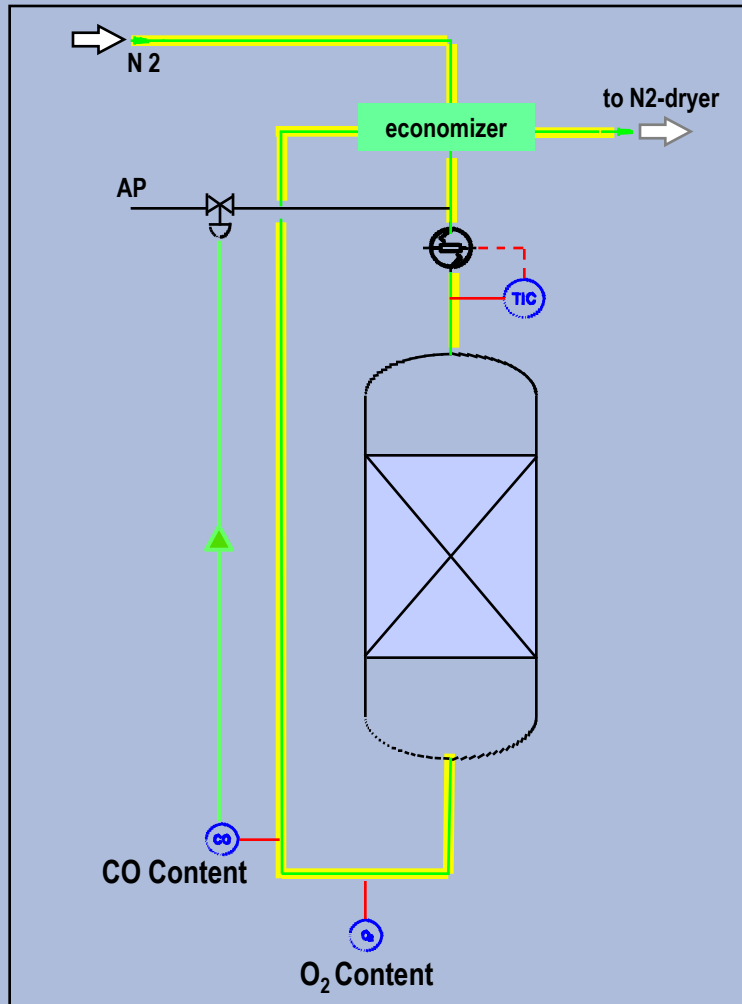
## SSP Plant Technology Single Stage Nitrogen Purification Unit

- ▶ oxygen content < 5ppm after purification
- ▶ total organic content (TOC)
  - < 10 ppm after purification
- ▶ water content
  - < 50 ppm after N<sub>2</sub> - dryer
- ▶ water and carbon dioxide as only effluents
- ▶ hydrogen not required
- ▶ only technical Nitrogen required (< 2% O<sub>2</sub>)
- ▶ CO-content used for control
  - no surplus of O<sub>2</sub> or TOC
- ▶ Generation of pure nitrogen
  - usage for other plants/consumers



## SSP Plant Technology

### Single Stage Nitrogen Purification Unit



Patented by Zimmer AG:  
DE 10043277  
DE 10314991

## Quality demands on final bottle polymer (after SSP)

### ▶ AA-reformation during pre-forming depends on:

- melt temperature
- residence time in injection molding system
- prior formation of vinyl ester-endgroups in polycondensation and SSP

### ▶ AA-reformation rate [ppm/s]

temperature	270 °C	280 °C	290 °C
Caripack (Shell)	0.0141	0.0249	0.0533 Zimmer process
comparison product	0.0236	0.0389	0.0780 (US-market)

### ▶ AA-content in preforms

projected requirement of the market depending on different application

water packaging: 1-3 ppm

CSD packaging: 2-5 ppm

general purpose: 4-8 ppm

## Bottle - PET resin processing

### Effect of Co-monomers DEG and IPA on the cycle time

Pre-form: 51 g ( bottle: 1,5 l)

Cycle time (sec)	IPA (wt %)	DEG (wt %)
18,0	2,5	1,3
20,0	2,0	1,3
21,5	1,5	1,3

## ▶ Optimization by Process Technology, Reactor Design

- Usage of different catalysts, Sb-based and Ecocat, possible
  - Impact on Polycondensation Reactors
  - Impact on SSP Reactor



## ▶ Optimization by Process Technology, Utilities

- Purified Nitrogen will be generated inside SSP for Continuous Polycondensation
- Nitrogen with organic load from Continuous Polycondensation will be cleaned in SSP
  - Reducing technical nitrogen consumption
  - Reducing propane gas consumption
  - Eliminating purified nitrogen consumption (generation)



## ▶ Optimization by Process Technology, Transfer Point

- Final product adjustment by COOH-level, IV-level, residence times
  - reduce catalyst consumption
  - reduce additive consumptions

## The **7-S** of Project Management (\*)

- Strategy** Requirements of the project and the means to achieve them.
- Structure** Organizational arrangement that will be used to carry out the project.
- Systems** Methods for work to be designed, monitored and controlled.
- Staff** Selection, recruitment, management & leadership of those working on the project.
- Skills** Managerial & technical tools available to the project manager and the staff.
- Style/culture** The underlying way of working and inter-relating within the work team or organization
- Stakeholders** Individuals and groups who have an interest in the project process or outcome

(\*) 7-S framework by McKinsey & Co., management consultants

## ▶ **Process Advantages:**

- Change downstream information into activities either in Polycondensation or in SSP independently
  - Changing / Adjusting parameter settings in both sections coordinated
  - Changing / Adjusting polymer composition (recipe)
- Process optimization for CPU and SSP together

## ▶ **Technological Advantages:**

- Interplay of forces from both, normally independent, production units
  - Off-streams used as feed-streams in the conjunctive facility
  - Common technological design philosophy is reducing number of sub-suppliers and by this costs for spare-parts

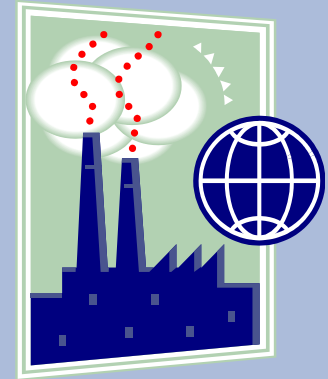
## ▶ **Economical Advantages:**

- Combined optimization reduces catalyst consumption and/or additive consumptions
- Optimized split of work-load (IV-lift) offers additional capacity

# PET Poly & SSP, Benefits for our Client (2)

## ▶ Management Advantages:

- Reduced work-load for clients Project Manager
  - One supplier = One's responsibility
  - Reducing amounts of cooperation meetings
- Client's problems are Supplier's tasks
- Support to achieve FDA approval



**Result: Minimizing the risks by achieving the project success factors!**

## ▶ High-Quality

Meet the outcomes of the project, both, functional and performance features.

## ▶ Within Budget

## ▶ On-time