



100%
eXtrusion
SHEET LINES

PET / R-PET SHEET

LINES FOR PET SHEET EXTRUSION



INTRODUCTION

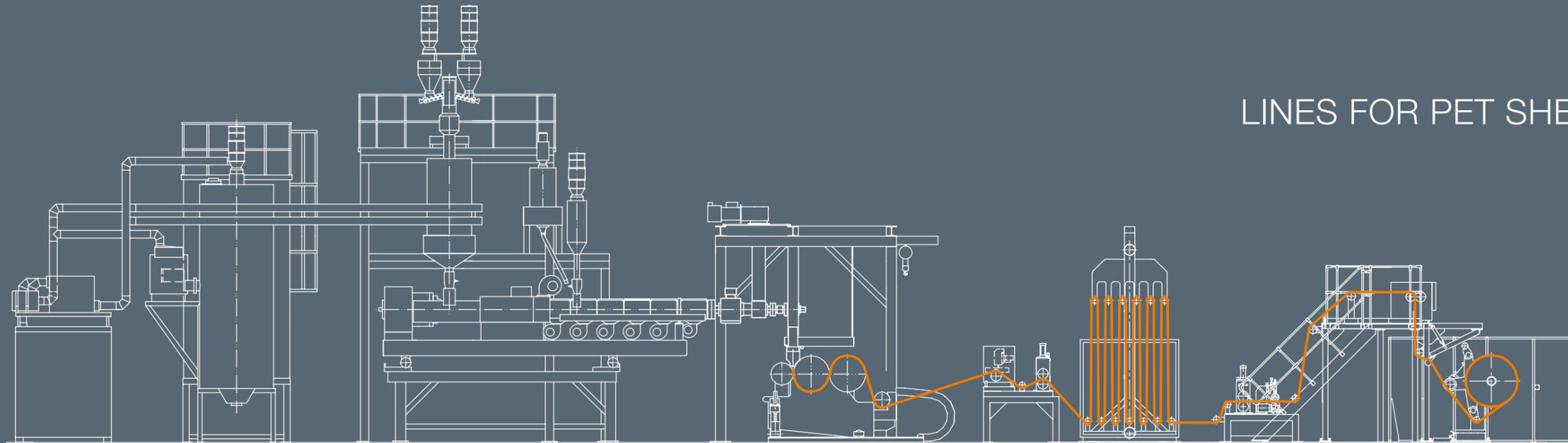
PET consumption has risen enormously during the past two decades. Bottles and textiles are the main products, but rigid packaging for food and other technical and consumer items also account for a significant volume. This development leads to the question as to why PET has become so attractive in comparison with other materials and whether or not its growth will continue?

Outstanding properties such as high transparency and stiffness, as well as excellent thermoformability have convinced an increasing number of converters to switch to PET sheet. Moreover, parallel to the continuous expansion in virgin PET consumption, a strong secondary market for flakes and repelletised material has developed. With continued introduction of legal regulations for collection systems many new opportunities for regional increases of this feedstock develop in further countries.

On SML sheet lines, designed for PET, also PLA can be processed.

A CHOICE OF THREE EXTRUSION CONCEPTS

Due to its vast expertise in the field of PET extrusion, SML assists its customers in the selection of the best extrusion system for their application and available feedstock.

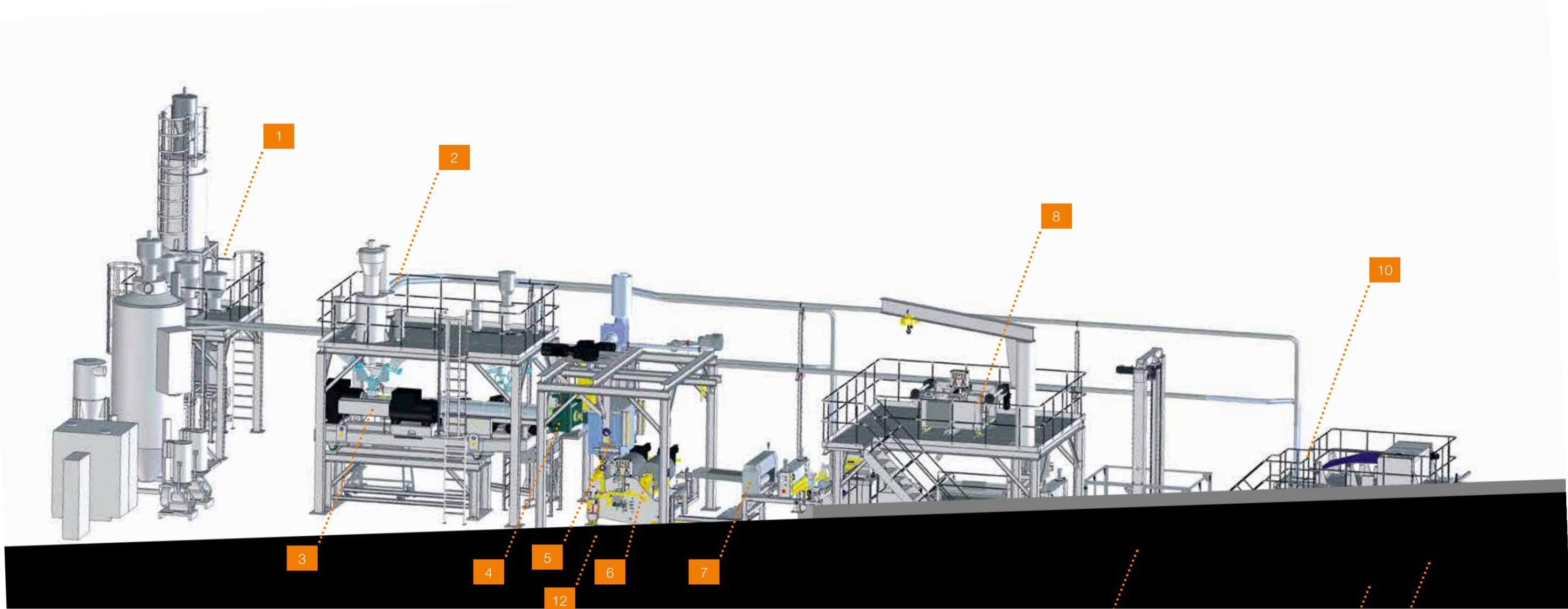


LINES FOR PET SHEET EXTRUSION

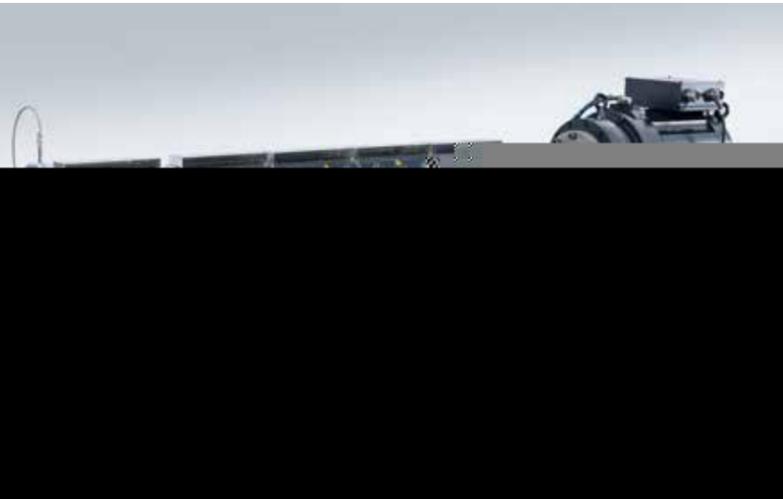
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standard extruder



Vacurema extruder

SINGLE-SCREW EXTRUSION WITH PRE-DRYING

With this system, minimised IV (intrinsic viscosity) reduction allows the production of top quality sheet. As compared to other equipment, single-screw extruders are robust and easy to operate. Two separate single-screw extruders with a dryer represent a typical co-extrusion for the production of standard 3-layer structures (A/B/A).

The raw materials are pre-dried through conventional dry air systems or in combination with infrared (IR) dryers.

In the dry air process, the individual components are usually dried separately, which provides maximum flexibility with regard to mixture changes. When drying A-PET regrind, the amorphous flakes have to be pre-crystallized or agglomerated in a separate unit. Standard dry air dryers are also suitable for processing PET-G, which is dried at lower temperatures.

In combination with IR-drying, which reduces drying times by more than half, the main components such as virgin material, flakes and regrind material are pre-mixed, then pre-dried in an IR-dryer before being further dehumidified in a conventional dry air dryer. Another advantage is gained from the ability of the IR-dryer to crystallize the regrind material in the same process. Small blenders mounted just above the inlet of the extruder feed the additives into the main material.

Single-screw extrusion with pre-drying is especially suitable for high percentages of virgin or repelletised material.

SML SINGLE-SCREW EXTRUDER OUTPUT:

Ø L/D	45/28	60/28	75/33	90/33	105/33	120/33	135/33	150/33	180/33
A-PET [kg/h]	100	200	350	450	600	800	1000	1350	1750

RECYCLING EXTRUDER (VACUREMA® SYSTEM)

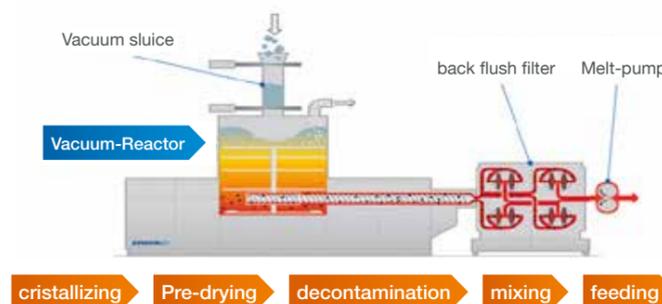
No discoloration, no integrated predrying of the input material and low energy consumption: The compact VACUREMA® system is ideal for processing PET bottle flakes and regrind. The process complies with the regulations of European and US authorities (EFSA/FDA). It is especially suitable for the decontamination of post-consumer bottle flakes and therefore applicable for producing single (mono) layer PET sheet for direct food contact purposes.

In its key components the system consists of a vacuum reactor, which is linked directly to a single-screw extruder. The patented pre-treatment at elevated temperature and in high vacuum before the extrusion process, removes moisture and migration materials from the feedstock very effectively. From the reactor the hot

material is fed under high vacuum into the single-screw extruder which is not in need of a degassing port.

For processing mixtures containing different materials, such as bottle flakes, regrind and virgin granules, the components are first pre-mixed in a separate dosing unit and then fed into the reactor. Additives are injected directly into the extruder by a side feeder behind the material inlet zone.

VACUUM REACTOR + SINGLE SCREW EXTRUDER - RECY SHEET



VACUREMA BASIC	output for an IV change of 0 to 4% (kg/h)	maximum output
1108 T	250	400
1109 T	300	500
1310 T	400	600
1512 T	600	900
1714 T	850	1000
1716 T	1100	1450
2018 T	1350	2000
2021 T	1800	2600
2321 T	2000	2900



conical twin-screw extruder

CONICAL TWIN-SCREW EXTRUDER

The conical twin-screw extruder offers great flexibility for the processing of flakes, regrind and virgin granules. Moreover, this extruder can also process other polymers such as PP or PS.

Depending on the moisture level in the raw material and the required sheet quality, PET can be processed without pre-drying in a twin-screw extruder, which has a positive effect on total energy consumption.

By combining a conventional pre-drying of washed bottle flakes with the high vacuum on the conical twin screw extruder the system complies with the regulations of European and US

CONICAL TWIN-SCREW EXTRUDER OUTPUT:

Max. output for PET (IR 0.65 - 0.8)	undried (*) kg/h	hot and dried (**) kg/h
MAS 24	30	35 - 40
MAS 45	220 - 250	250 - 350
MAS 55-L	500 - 550	550 - 600
MAS 75	800 - 900	900 - 1,000
MAS 90	1,300 - 1,400	1,500 - 1,600
MAS 93	- 1,600	1,800 - 2,000
MAS 93-S	- 1,800	2,000 - 2,200

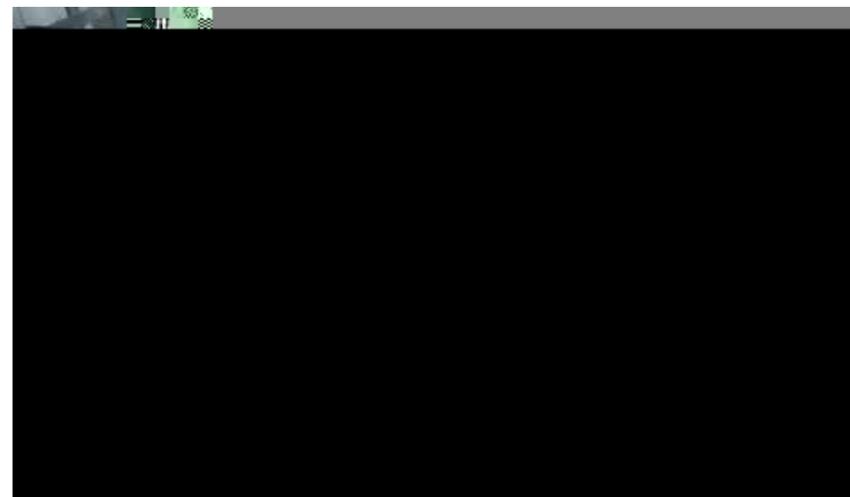
(*) max. ~8000ppm, (**) >140°C, max. ~50ppm

authorities (EFSA & FDA). So washed PCR bottle flakes can be converted straight into “excellent quality – 100% Food Grade-sheet”

When material is additionally pre-dried before processing, the IV loss is lower and the values for AA-Content and yellowing are supreme, which, as compared to the process without pre-drying, results in superior sheet quality from the same material.

Owing to their ability to control the precise filling rate of the extruder, gravimetric loss-in-weight dosing units are generally employed with twin-screw extruders.

Due to its conical shape, the conical twin-screw extruder provides advantages relating to the feeding section, because it is larger than the screw diameter at the outlet. Hence the pressure build-up is significantly higher than that of a parallel twin-screw extruder. This effect opens the way to operations using a backflush filter without an additional melt pump in front of it.



continuous double piston filters

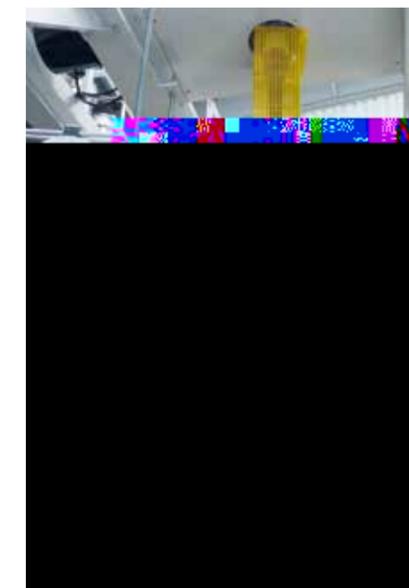
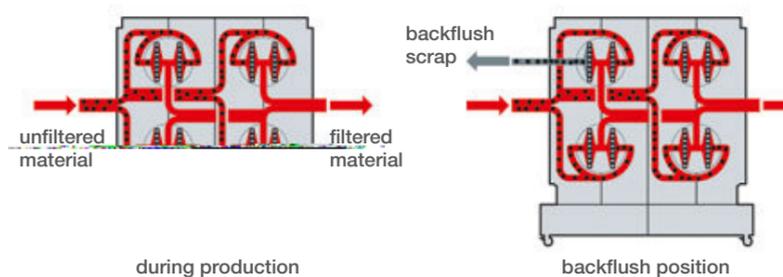
FILTRATION SYSTEMS

Different filter types are selected in line with the extruder design and the expected level of impurities in the raw material:

- Single-piston, hydraulically actuated discontinuous filters
- Double-piston (2 or 4 cavities), hydraulically actuated continuous filters
- Backflush filters with up to 12 cavities

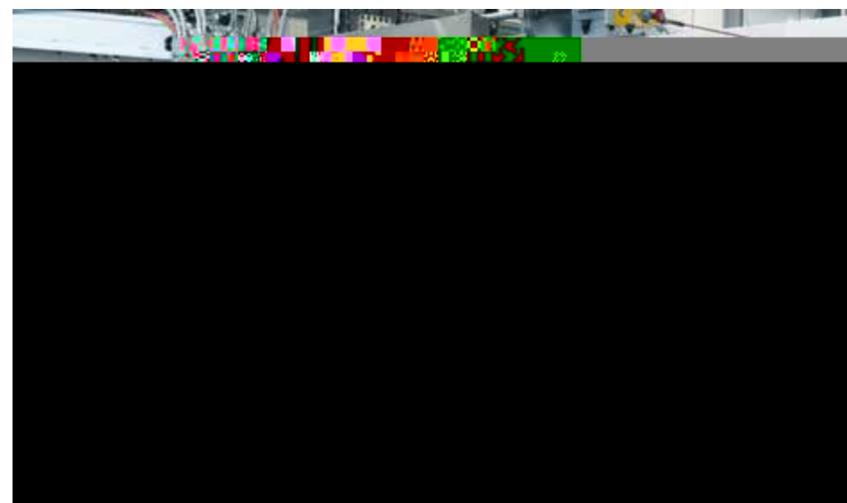
In order to guarantee stable pressure and good melt homogenization in front of the die, SML PET lines are equipped with melt pumps and static mixers.

SCHEMATIC DRAWING 8-CAVITIES BACK-FLUSH FILTER



tool unit with continuous double piston filter and melt pump

die splitting system



horizontal roll stack

FEEDBLOCK AND FLAT DIE

As a leading supplier of high-quality PET sheet lines, SML relies exclusively on reputed partners for its feedblocks and flat dies.

A 3-layer A/B/A sheet structure with thin outside layers is typical for the following main reasons:

- The opportunity to run with virgin material only in the two outside layers, while using recycled material in the middle layer. This avoids contact between the packaged goods and recycled material (food contact regulations).
- The opportunity to run the anti-block additive only in the thin outside layers, for cost reasons.
- The opportunity to run with other additives (Masterbatch, foaming agent) in just the center layer.
- The opportunity to produce GAG sheet (PETG/APET/PETG).

Feedblocks with up to seven or nine layers are also used for special applications such as PET sheet with functional layers such as barrier and/or peel or seal layers.

As far as the flat die is concerned, manual and automatic dies with special features such as lip heaters, are used for PET sheet lines. Dies are usually deckled with external or internal deckles or a combination of external/internal deckles.

The SML die splitting system provides quick and safe opening of the die for cleaning purposes. The die stays in its original position in the machine and remains electrically connected for heating!

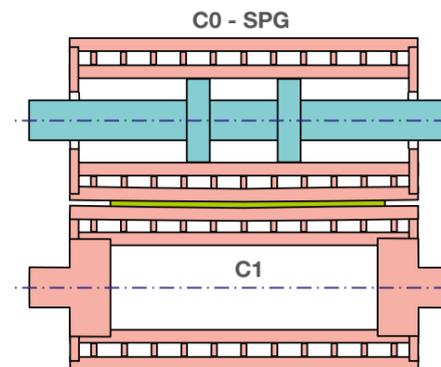


tool unit with melt pump, static mixer, feedblock and flat die

ROLL STACK

SML PET lines are highly respected in the market because of their outstanding roll stack technology, which results in superior thickness tolerances. All the SML roll stacks for PET sheet are equipped with the specially designed SPG (Smart-Parallel-Gap) C0 polishing roll.

Moreover, the C1 (main) and C2 (secondary) cooling rolls with thin outer shells enable a high specific output, due to improved heat transfer. All three rolls are hardened to 60+/-2 HRC, chromium plated and polished to a high-gloss mirror finish. Each roll is equipped with a separate water temperature control system and an individual, highly accurate drive system. The maximum mechanical speed depends on the basic line configuration and factors such as extrusion capacity, width and thickness range. SML sheet lines for PET are available for mechanical line speeds of 50, 70 and 100 m/min.



For the typical thermoformable PET sheet thickness range, SML recommends a horizontal roll stack, which offers important advantages such as:

- The possibility of positioning the melt bank on the polishing roll side (C0), or on the side of the main C1 cooling roll, which provides optimum sheet surface quality.
- The melt exits the die vertically, due to gravity, and is not pulled over the edge of the die lip.
- No melt sagging prior to roll contact, as it can occur with vertical roll stacks. Less pressure for polishing is required because the melt is not cooled by roll contact before it enters the gap. This results in lower internal stress in the sheet.



flat die in operation position



inclined roll stack

For very thick and heavy gauge sheet SML supplies roll stacks with inclined roll arrangement, which is the optimal design for these products.

In its standard designs, SML offers gap adjustment using manually adjustable spindles with scales and readings. As an option, motorized gap adjustment is available. AC servo-motors drive the spindles and the values are displayed on a touch screen in the control panel on the roll stack and stored in the SMILE recipe control system.

A very useful optional feature is the nip load measurement system, which shows the actual pressure (N/cm) in the polishing nip, online.

Depending on thickness and output, additional post cooling rolls can be mounted on the roll stack after the C2 roll.

STANDARD SML ROLL STACK CONFIGURATIONS:

Diameter mm Roll combination	Roll width in [mm]							
	1050	1200	1400	1650	1800	2000	2200	2400
CO SPG / C1 / C2	300/400/400		330/400/400					
CO SPG / C1 / C2	370/490/490	370/490/490	370/490/490	370/490/490				
CO SPG / C1 / C2	370/600/600	370/600/600	370/600/600	430/600/600	430/600/600	430/600/600	490/600/600	490/600/600
CO SPG / C1 / C2	370/700/700	370/700/700	370/700/700	430/700/700	430/700/700			
CO SPG / C1 / C2					430/715/715	430/715/715	490/715/715	490/715/715



inline thickness measuring unit with inductive / capacitive sensor

GAUGING SYSTEM

In answer to the various regulations in customer countries and specific product needs, SML supplies different automatic gauging systems:

- Inductive / capacitive sensors
- Air caliper systems
- Radioactive Beta-ray sensors (Krypton 85 or Sr 90)
- X-ray sensors
- Laser shadow

All these systems are available for dies with manual adjustment or automatic profile control and are equipped with a control for the speed of the main cooling roll C1, to maintain the value of the thickness setting in machine direction.



inline thickness measuring unit with Beta-ray sensor

EDGE TRIM CUTTING/REMOVAL

Edge trims are cut off using static blades or motor-driven circular knives. A precise cut is required for excellent winding quality. The edge trim is usually pulled into an inline grinder. The regrind is then either filled into big-bags for interim storage or refeed directly to the main extruder via a conveying screw mounted above the extruder inlet opening.



edge trim cutting

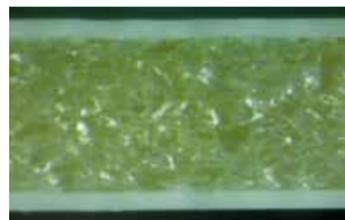


roll stack

PRODUCTION OF FOAMED PET SHEET

An upcoming market for PET sheets is the production of 3-layer A/B/A sheet, where the middle layer is foamed. Foaming can be done chemically or also physically by additional injection of gas.

The way how the foaming is done is depending also on which of the 3 extrusion system is used. For Single screw extruder, or Recycling extruder (VACUREMA System) or Conical twin-screw extruder SML can use different systems.



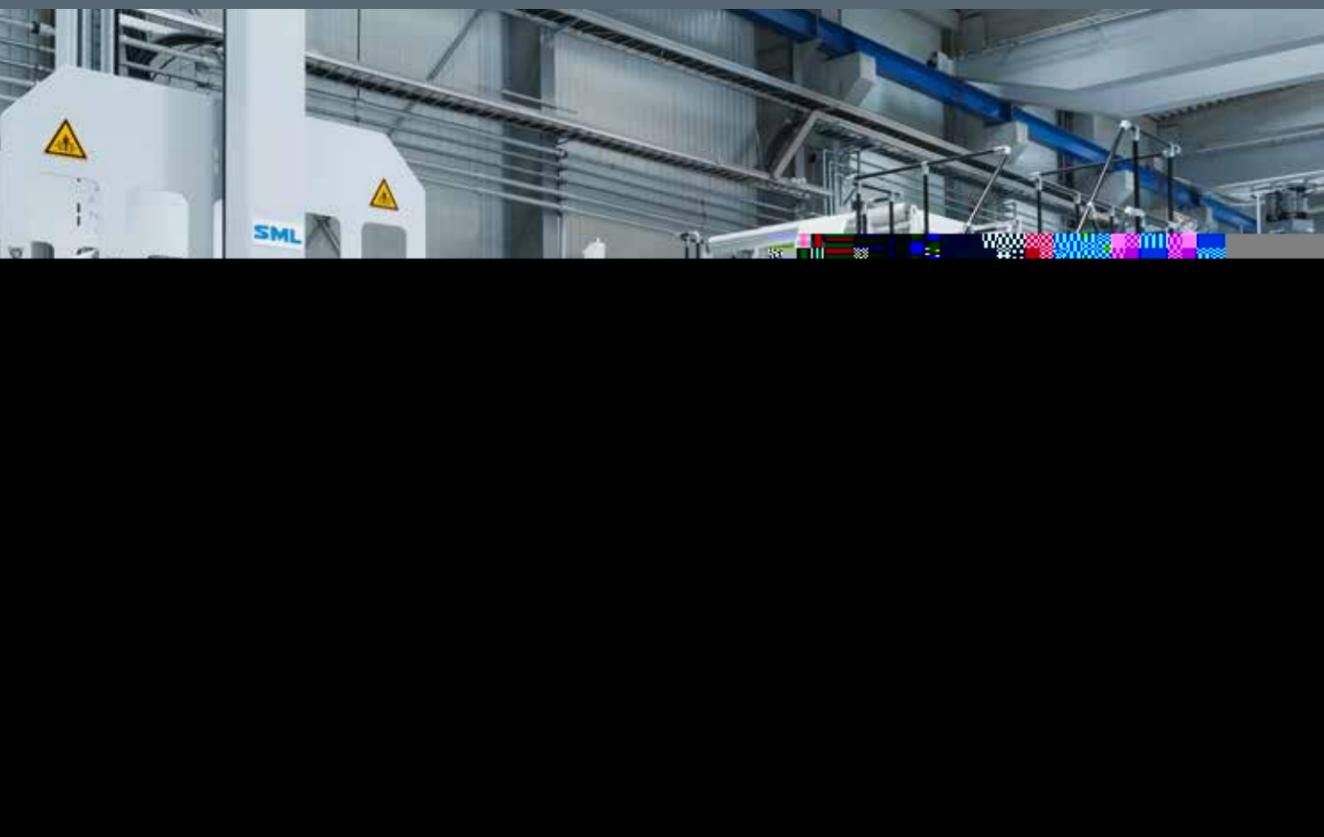
Cross section 3-layer sheet with foamed middle layer



bobbin foamed sheet

HIGHEST QUALITY PRODUCTS





WINDING SYSTEMS

SML customers can select from a wide range of different semi- and fully-automatic sheet winding systems for PET. Semi-automatic winders work in combination with an accumulator, which picks up the sheet during the manual change of the roll in the winder. All winders are designed and built by SML.

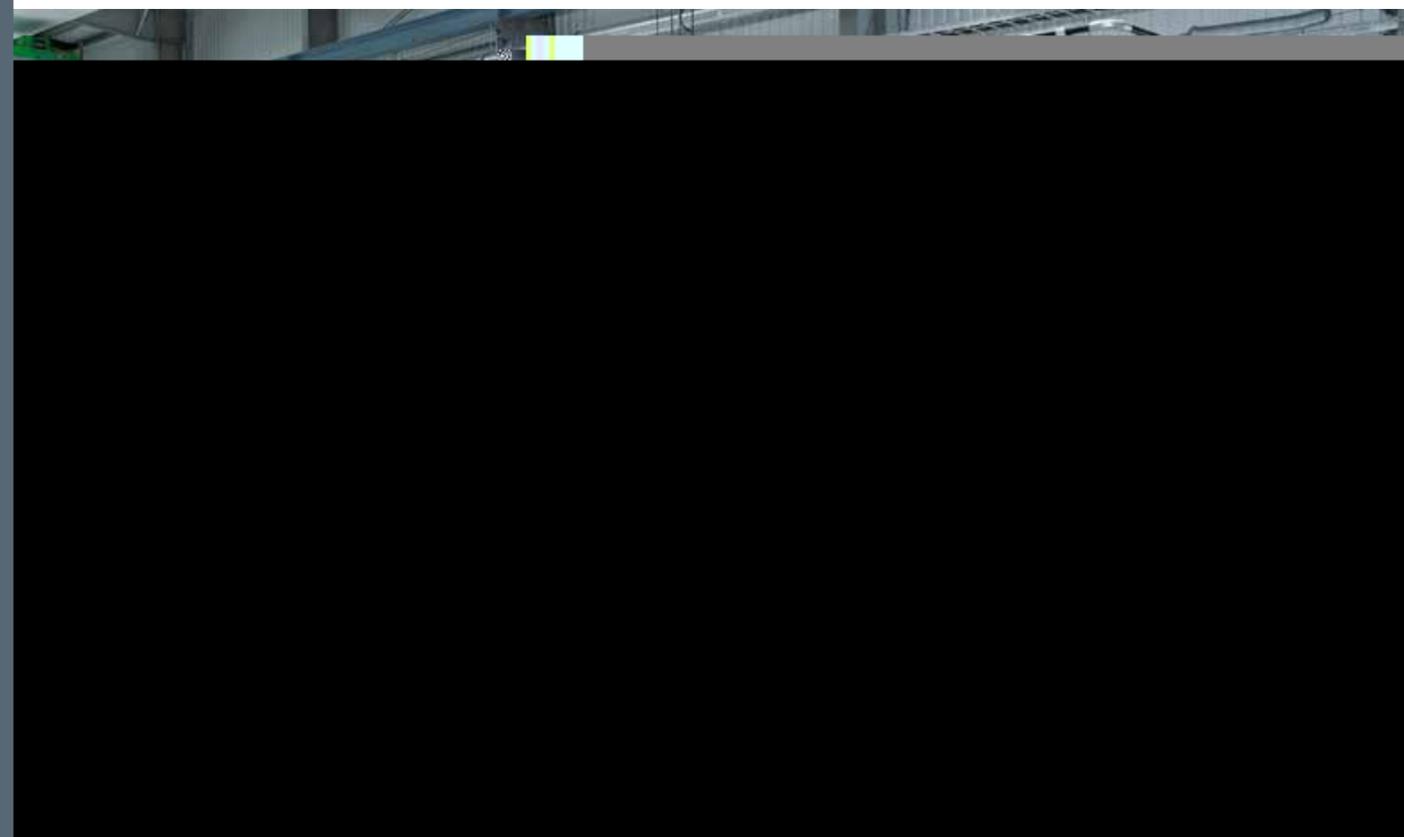
The accumulator works from a bottom to top position, while a torque-driven servo-motor generates storage movement and precise web tension.

- Film capacity: standard 38m and 50m, others possible on request
- Guide roll diameters of 120 and 160mm available
- Access doors at operation side for easy sheet feeding into the accumulator in the bottom position

SEMI-AUTOMATIC SHEET WINDERS

These winding systems are known for excellent production reliability at an attractive cost level. Semi-automatic winders in combination with an accumulator facilitate safe and easy roll changes by the operators.

SML offers different winding systems, depending on customer requirements and the available floor space.



WINDER W500 A-FRAME

This is a single- or multi-web winder with two A-frame winding trolleys for each web. Winders are equipped with electric drive.

After the roll change procedure, an operator removes the A-frame trolley with the finished roll from the winder. The roll itself has to be lifted from the trolley by means of a crane or a forklift.

The winder W500 is a comfortable and economic solution for large roll diameters.



WINDER W600 CANTILEVER

This single- or multi-web winder has two winding stations with winding shafts for each web, supported on just one side.

After the roll change procedure, a manually operated lifting trolley is used to remove the finished roll from the cantilever shaft, which remains in the winder. This system ensures maximum operator convenience, especially in the case of small diameter rolls and frequent roll changes.



WINDER W550 COMBINED A-FRAME / CANTILEVER

This winder combines the advantages of the A-frame winder W500 and the cantilever winder W600. The A-frame winding trolley is typically used for making jumbo rolls, while the cantilever winding shaft is best suitable for making frequent roll changes when producing small rolls. So the winder W550 stands for increased flexibility and production reliability in making roll diameters from small to big.

The winder can be easily modified from an A-frame winder into a cantilever winder. The A-frame trolley only has to be moved out and the cantilever shaft is quickly fixed to the drive disc.





WINDER W900 TURRET

The semi-automatic turret winder is easy to operate, and requires less floor and handling space than A-frame winders. If slit rolls are produced, the appropriate number of turret stations is installed.

Because of its short, internal film guideways, the turret winder is especially suited for medium roll diameters and the production of thin sheet.

As an option, all the electric semi-automatic winders are available with friction winding shafts, which makes it possible to wind two or more webs onto one shaft.



WINDER W2000 TF FULLY AUTOMATIC

As opposed to semi-automatic winders, the fully automatic sheet winder enables roll changes at full line speed, with the result that no accumulator is required. The short web path in the winder and the automatic attachment of the film to the new winding core represent advantageous features, especially with regard to thin films. Owing to the horizontal shaft movement principle, the roll remains in an optimum winding position until the very last moment before crosscutting, thus guaranteeing perfect winding quality up to the last layer on the roll.

The winder W2000 TF is designed for winding PET sheet in a wide thickness range. It is equipped with a web tension-measuring roll in the winder entrance, which separates winding tension from upstream web. The winder is equipped with a powerful guillotine-cutting unit. After cutting, the leading edge of the film enters a guide system and is pressed onto the new prepared winding core. The winder W2000 TF is also designed for precise gap winding.

The upper side of the sheet is wound on the inside. The winder W2000 TF can be equipped with optional friction winding shafts for the production of inline slit rolls. In this case, two adjustable banana rolls are positioned behind the slitting unit in order to separate the webs with a small clearance in between. In the friction-winding mode, the pneumatic pressure in the winding shaft controls the winding tension in line with the start tension and the selected taper curve.

The finished roll and the winding shaft are transported onto a moveable lifting table by an overhead robot, which then pulls the rolls off the clamped shaft. The complete roll and shaft handling process is fully integrated into the winder's automatic mode.



e-container

Winding	W500	W600	W550	W900	W2000
Net film width max.	950mm/1,100mm 1,300mm/1,550mm 1,700mm/1,900mm	650mm/950mm 1,100mm/1,300mm 1,550mm	950mm/1,100mm 1,300mm/1,550mm	650mm/950mm 1,100mm/1,300mm 1,550mm/1,700mm	1,450mm/1,650mm 1,850mm/2,050mm
Number of webs	up to 3	up to 3	up to 3	up to 3	up to 3
Core ID (inch)	3, 6, 8	3, 6, 8	3, 6, 8	3, 6, 8	3, 6
Thickness range	150-1,600µm	150-1,200µm	150-1,600µm	150-1,200µm	100-1,000µm
Max. mech. speed	70 m/min	70 m/min	70 m/min	70 m/min	100 m/min
Accumulator	yes	yes	yes	yes	no
max. roll diameter up to*	1,200mm	1,000mm	1,200mm	1,200mm	1,100mm
	2,000mm	1,400mm			

(* Depending on shaft diameter, roll width and number of webs)

SMILE CONTROL SYSTEM

An innovative, intuitive and operator-friendly human-machine interface (HMI) with two 17-inch touch screens provides all the functions needed by operators and maintenance personnel to handle the complete line. Everything, from the input of the ratio of each raw material to the parameters of the winder can be dealt with from the main terminal, which is located in the casting section. A second touch screen at the winder that is linked to the main terminal allows winding parameter adjustment directly in the field of vision for the process.

Different access levels and features such as alarm management, recipe administration and remote service via ethernet/internet are standard. For extended trend analysis and quality documentation, data can be transferred to a data logging system via a separate PC, or existing data collection systems. The electrical equipment is either installed in an e-container or, depending upon the space requirement, in e-cabinets. Both customised solutions are supplied complete with electrical engineering, wiring and air-conditioning equipment. Only first choice and proven components are used for each device.

ADVANTAGES

- Centrally operated touch-screen monitor, displaying all relevant data
- Central control of all production parameters
- Industrial Ethernet Powerlink connection to decentralised I/O points
- Process data analyses
- Integrated OEE (Overall Equipment Effectiveness)



control panel



PET sheet line with thermo-lamination



extrusion coating

PRODUCTION OF PET/PE OR PET/BARRIER STRUCTURES

When sealability or barrier functions are required, the PET sheet needs to be supplemented with different polymer layers or films. Such functional outer layers can be added in different ways, but whatever the method, it can be integrated inline into a PET sheet line.

**BASED ON ACTUAL EXPERIENCE
SML OFFERS THE FOLLOWING SOLUTIONS:**

1. CO-EXTRUSION

This process provides outstanding optical properties and excellent adhesion between the individual layers. However, owing to



the very different material melt viscosities of PET on one side and PE or barrier material on the other, the process is difficult to handle and adjust during product changes. Co-extrusion is therefore recommended for large production lots and a low number of product variations.

2. ADHESIVE LAMINATION

This is a very efficient process to achieve the highest possible bonding strength and maximum flexibility. The PET film is extruded independently from the lamination process, which allows recovery of 100 per cent clean edge trims.

The lamination film enters the lamination station from an unwinder and can be changed very easily, in order to obtain a final product with completely different properties. The lamination process is not started before the PET sheet quality has been stabilized, and for this reason the scrap rate is very low.

3. THERMO-LAMINATION

This process is easy to handle and offers very efficient production. Here also the PET sheet is produced independently from the lamination process. The surface of the PET sheet and the lamination film are heated up by infrared heaters prior to the lamination point in a pressing roll duo. Basically, the strength of the bonding with the PET film depends on the properties of the lamination film and is generally lower than that provided by adhesive lamination or co-extrusion.

4. LAMINATION AT THE ROLLSTACK

This is a possibility to do lamination with low additional investment costs in machinery. Here the lamination is done directly at the roll stack by utilizing the existing heat of the extruded PET.

This method of lamination is mainly for occasional, small production runs, as there are certain limitations and disadvantages in this process, compared to others.

5. EXTRUSION COATING

The independently produced PET film is guided through an extrusion coating station with one or more extruders. This production method is cost-efficient and the product quality, bonding strength and transparency are excellent. Moreover, this method covers a large diversity of products.

PET/PE PRODUCTION - COMPARISON

	Co-extrusion	Adhesive lamination	IR-Thermo-lamination	Lamination on the roll stack	Extrusion coating
Adhesion	+	++	-	-	+
Flexibility	-	++	+	-	+
Investment	+	-	+	++	--
Personnel	++	-	+	+	--
Output	-	+	+	--	++
Edge trim loss	--	++	++	--	+

NOTES:

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EXTRUSION LINES – ENGINEERED TO PERFORM ►

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