

WORLD'S MOST PRECISE SLIDE, SLOT AND CURTAIN DIES FOR PREMETERED COATING.



**TSE TROLLER
COATING SECRET**

THE FUTURE IS HERE

One of the biggest challenges for mankind in the near future will be energy – firstly saving energy and secondly producing energy with environmental friendly procedures.

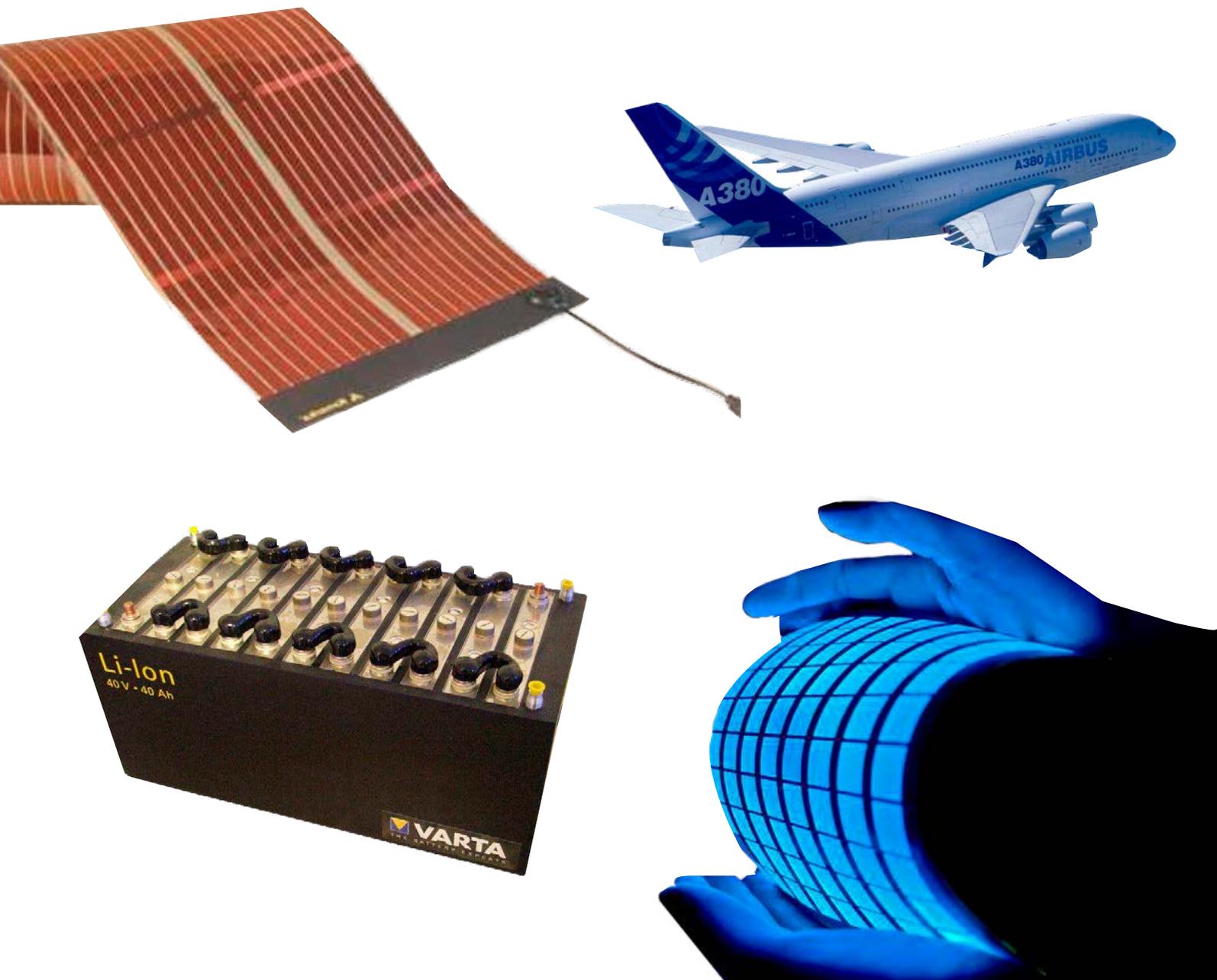
As an example which explains the importance: At the moment approximately 20% of all energy produced on earth is used just for lighting with very low efficiency.

Modern manufacturing methods help to develop new eco-friendly products such as Li-Ion batteries, OLED, OPV and carbon fibres, all helping to save resources.

One of the major challenges for companies is to fulfil the future requirements of the markets and the environmental regulations.

Controlling the manufacturing costs during the production of goods is necessary for the economic success of a company. Therefore not only the investment is important but also the operating cost of a production facility including material consumption.

Modern manufacturing methods help to maintain the success of a company.



Photos courtesy by VARTA, OLEDWORKS, KONARKA and by AIRBUS

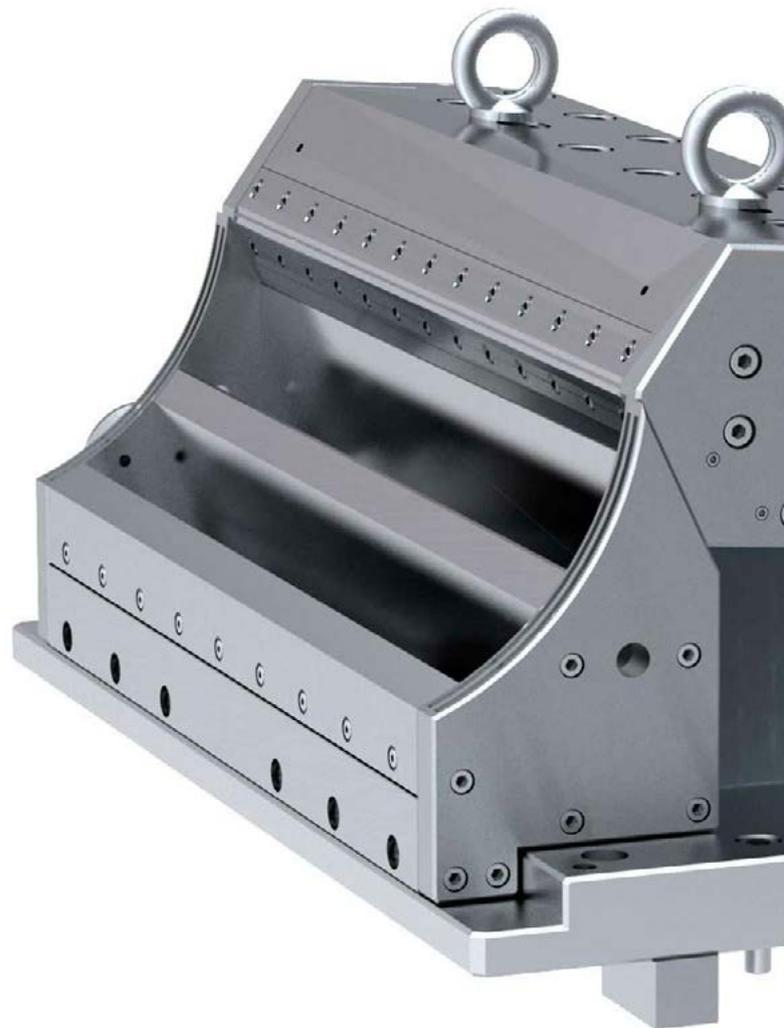
PIONEERING PRE-METERED COATING SOLUTIONS

More than 60 years of know-how in the development and production of pre-metered coating dies have made TSE TROLLER a world leading specialist in the applied coating technology sector. The company based in Murgenthal, Switzerland, has developed advanced coating solutions which have paved the way for the future.

TSE TROLLER brings you the benefit of unrivalled precision tailored to your specific needs. Our coating dies, designed exclusively for pre-metered applications, satisfy almost all coating needs. We specialize in high precision multilayer coating and complex coating dies.

At TSE TROLLER we maintain secrecy about our own achievements and those of our customers. Our best reference is silence.

**Therefore don't ask about.
But ask.**



Single Layer Slot Bead Die with Vacuum Box

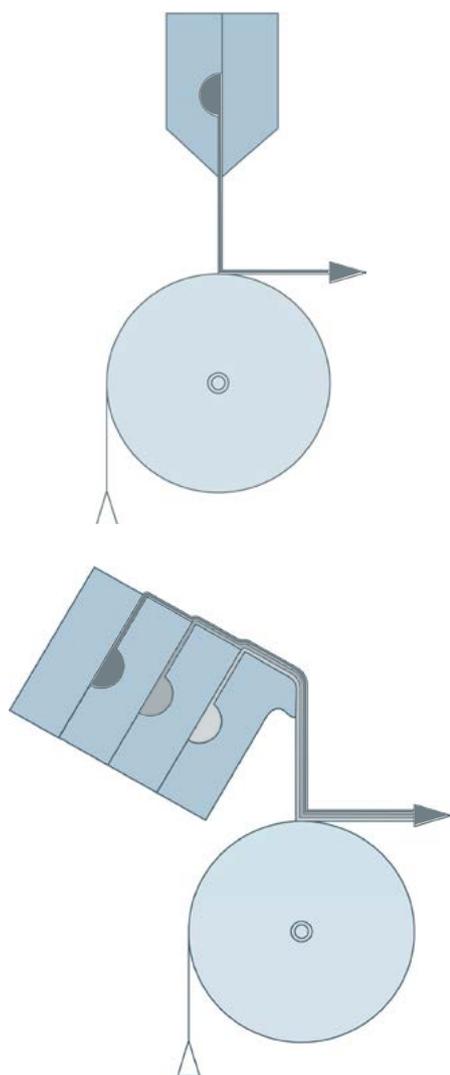
PROCESS DESCRIPTION OF PRE-METERED COATING

Pre-metered coating methods are a group of technologies which are used for the continuous application of functional fluids on substrate in web format.

Unlike the “self-metering” methods, a uniformly operating pump delivers the necessary volume of fluid to maintain the desired wet film thickness on the substrate to be coated for a given working width and at the planned working speed. This fluid quantity is held constant, e.g. by flow control. The coating liquid is then distributed over the desired working width by means of a coating die. For this purpose, a distribution system consisting of a distribution chamber

and a subsequent metering slot is incorporated in the die. The design of this distribution system, in terms of flow technology and the uniformity of the metering slot height, are the key contributory factors to uniform distribution of the fluid across the working width. The coating fluids may contain water or organic or inorganic solvents and for some applications may be used without a solvent (100% solids). As in the case of all other coating techniques, the properties of the fluids must be adjusted to the needs of the pre-metered techniques.

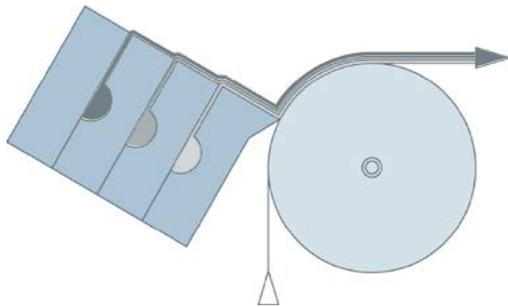
CURTAIN COATING



The curtain coating technique enables layers ranging from thin to thick to be applied. The application area ranges from moderate to very high coating speeds, well above 2'000m/min. Curtain coating methods enable one or more fluid layers to be applied in a single operation. The number may exceed ten to suit the particular application and depends on the shape of the coating die (slot die or slide type die). When the curtain coating method is used, the die lip is positioned at a great distance above the web to be coated, the fluid drops downwards in free fall as a closed liquid curtain and is deposited on the substrate.

In the case of the curtain coating method with a slot die, the exit slot is orientated downwards while in applications with a curtain slide die the fluid film leaves the exit slot(s) upwards and then flows down the inclined surface (“Slide”) before leaving the die body at the lip and passing into the curtain. Because of the great distance between the lip and web, the curtain coating method is largely unaffected by linear coating defects and produces a very uniform layer on uneven surfaces (contour coating). For this application method too, TSE develops and produces coating dies and also various accessory components which are used to optimize the application window.

SLIDE-BEAD COATING

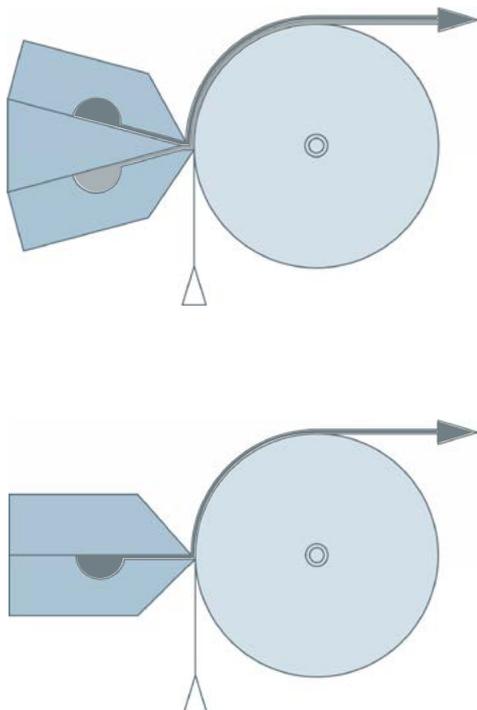


The slide-bead coating technique enables layers of medium to large thickness to be applied. The application range extends from rather slow coating speeds up to average speeds of 300-400m/min. Slide-bead coating enables one or more fluid layers to be applied in a single pass to the substrate which is to be coated; the number of layers may exceed ten, depending on the particular application.

When the slide-bead coating method is used, the fluid film emerges from the exit slot of the die in an upward direction and then flows down the inclined surface (“Slide”) before bridging the narrow bead gap between the die lip and the running web – in much the same way as when the slot-bead coating method is used.

To achieve the most uniform possible film thickness on the substrate to be coated in cross-machine direction, the parallelism of the bead gap must be set with great precision as must the slot height. An inherently stable and highly accurate positioning system is required. For this purpose, TSE develops and produces coating dies and also various accessory components which are used to optimize the application window.

SLOT-BEAD COATING



Slot-bead coating permits the application of layers which may range from very thin to relatively thick, depending on the particular use. The application area extends from very slow coating speeds of a few cm/min up to medium speeds of 300-400m/min.

By means of slot-bead coating techniques, one or more fluid layers can be applied in a single pass onto the web which is to be coated; the number of layers is limited. In the slot-bead coating method, the fluid film leaves the exit slot of the coating die and directly bridges the very narrow bead gap between the die lip and the running web.

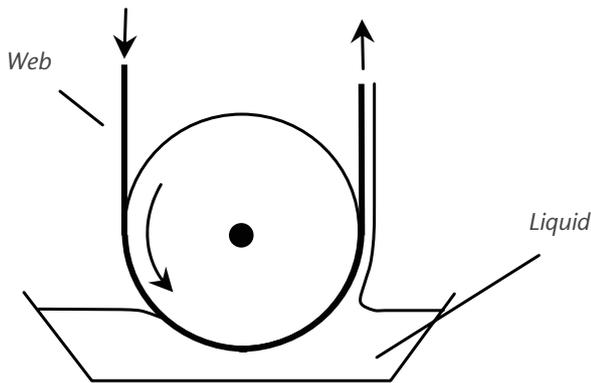
To achieve the most uniform possible film thickness on the substrate to be coated in cross-machine direction, the parallelism of the bead gap must be set with great precision as must the slot height. For this purpose, an essentially stable and highly accurate positioning system is required. For this application method, TSE develops and produces dies and also various accessory components which are used to optimize the application window.

SELF-METERED VS. PRE-METERED COATING SYSTEMS

Self-metered coating systems have been standard in the industry since the industrialization of coating while pre-metered methods were introduced mid of last century by the photographic industry. Since then it has also become state-of-the-art technology in the special paper or adhesive industry. The advantages of pre-metered coating systems such as very uniform cross profile, optimized and low liquid consumption, higher coating speed and the possibility to coat several layers simultaneously has further spread these methods into many new fields of the industry. While the liquid formulation and viscosities in self-metered systems do

change from the beginning to the end of the batch, the formulations in the pre-metered systems remain the same over the entire batch. This results into uniform coating thickness in longitudinal direction. The achievable cross profile tolerances are much narrower in case of the pre-metered systems as compared to self metered systems. Therefore, with pre-metered coating the liquid savings are significant. Due to short residence time in optimized dies it is possible to coat reactive fluid systems, which gives more freedom in designing functional layers.

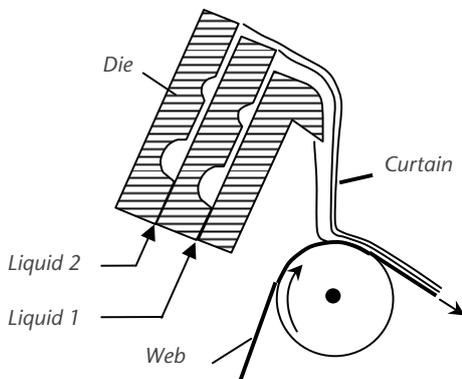
SELF-METERED COATING SYSTEM



Example: Pan (Dip) Coating

- Simple methods
- Lay-down depends on liquid properties and web speed
- Formulation changes affect lay-down
- On layer applied at the time

PRE-METERED COATING SYSTEM



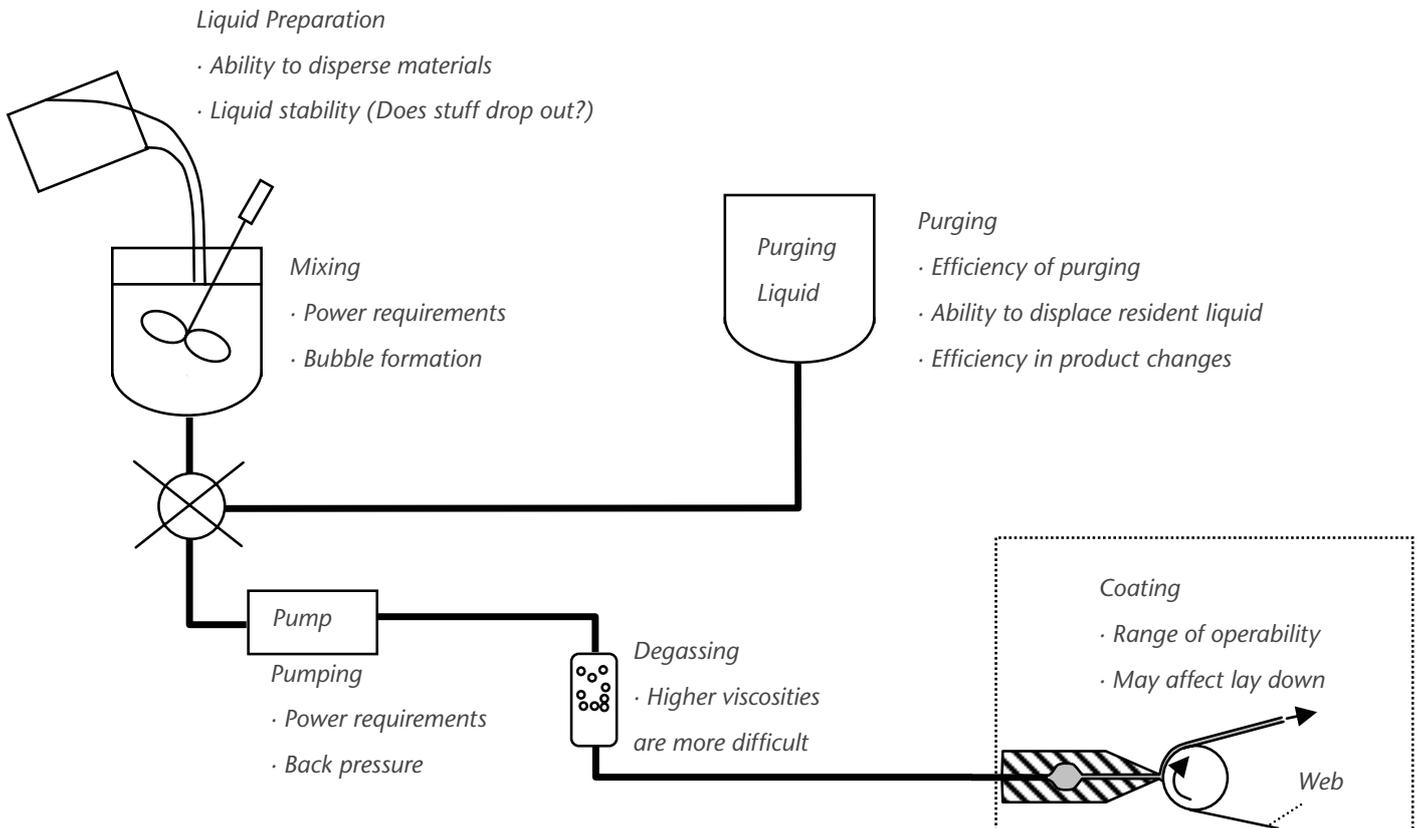
Example: Dual Layer Slide Curtain Coating

- More complex, requires a die distributor
- Lay-down is specific within operating range of process
- Formulation changes do not affect lay-down
- Multiple layers coated simultaneously
- Multi component liquids usable

LIQUID PREPARATION

The liquid preparation takes a key role in pre-metered coating. Depending on the range of different liquids to be prepared and dosed, the selection of pump and degassing unit has to take in account the different behaviors of each liquid. The capacity range of the pumps has to cover the entire flow rates, while the operating window of the dosing pumps should not be utilized to its minimum or maximum. Hence the pumps should operate in the middle of its working ranges. Very high as well as very low pump loads should be avoided and can lead to strips, pulsations or other unwanted effects in the coating. TSE can make some advises on the design of such liquid preparations or can offer entire systems with capable partners in this field.

To avoid die distortions during operation, the temperature of the die as well as the entering liquid must be equal in small tolerances. A water circuit using tempering holes in the die keep the temperatures in the die at constant levels. The liquid preparation must also be equipped with a temperature control system which is coupled with the system of the die in order to guarantee that both temperatures are equal. For some applications multi component liquids must be dosed. The pre-metered coating method allows the mixing in a static mixer located short before the entrance into the die. The varieties in the coating industry with different substrates and liquids are extremely wide. TSE has strong knowledge basis to cope with all different requirements.



CORE COMPETENCE IN PRE-METERED COATING SYSTEMS

The dies of TSE Troller are of highest quality. Every die plate that is made at TSE is of excellent quality and polished to perfection. The accuracy and quality that you can expect when ordering from TSE are surpassed by no one.

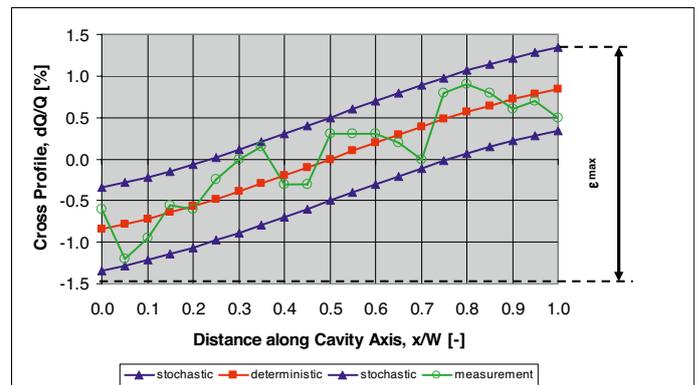
At TSE we use the most precise equipment for building, measuring, and testing our dies in order to be certain that we will produce equipment of the highest possible quality. This measuring device is accurate down to 0.1 microns.

Beside precision and surface quality it is the design of the cavities that plays a crucial role in achieving a good function and performance of the die. TSE has wide know how in modeling different liquids and is in contact with leading institutes and universities in material science world-wide. Target of modeling the dual cavity distribution system is a uniform cross profile of the coated film on the substrate as well as long intervals between die cleaning cycles to achieve high coating line efficiency – for a wide range of applications of course.

In the diagram the uniformity of the film thickness is shown over the width of the die – measured from the feed port. For a centre fed die the resulting profile will be symmetrical relative to the centre line of the die. The red curve shows the theoretically calculated flow profile for a specific application. The blue curves represent the level of mechanical precision and the green line stands for the actual measurement data of the finished die.



Measuring a dual cavity slide curtain die plate



Cross profile band, defined by slope and width

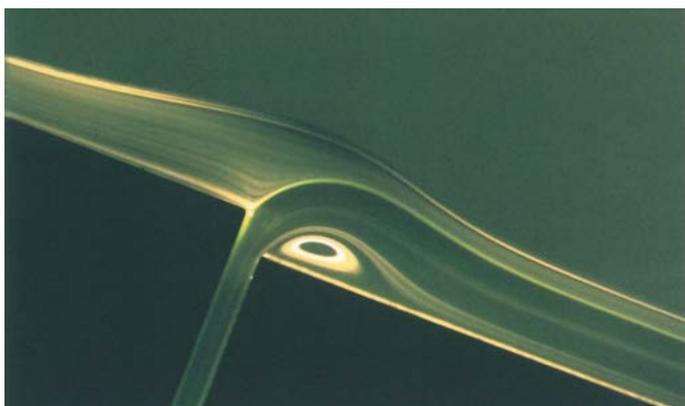
HIGH PRECISION MANUFACTURING

Depending on the requirements of the coating cross profile tolerances, TSE can manufacture dies in different precision levels defined in the following table.

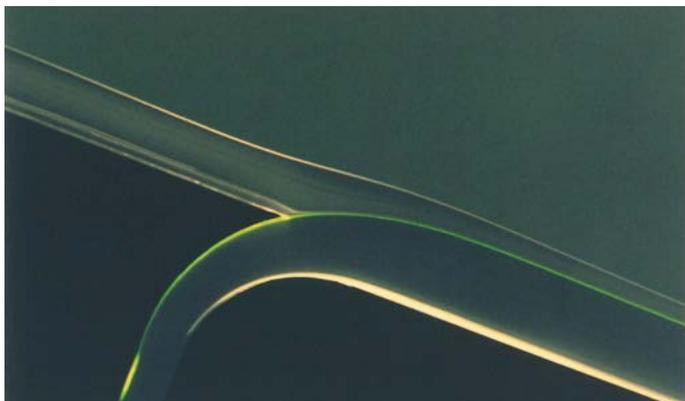
Of course the high precision manufacturing experience allows customers to have also coating dies repaired, overhauled or modified, regardless if they are manufactured by TSE or not.

Level of mechanical precision	Precision of nominal slot depth $\pm\mu\text{m}$	Precision of inner slot surface (System 1) $\pm\mu\text{m}$	Precision of outer slot surface (System 2) $\pm\mu\text{m}$
B	20	6.00	6.00
A	10	4.00	2.50
A with changeable lips	10	4.00	3.00
AA	5	2.00	1.00
AAA	5	1.00	0.50
AAAA	5	0.50	0.25

KNOW HOW ABOUT FLUID DYNAMICS



Maintaining optimum laminar flow conditions is crucial especially for multilayer applications, but as well for applications with particle loaded liquids and / or with reactive components. Vortices as shown left at the exit of an upwards orientated slot of a multilayer slide die might create a recirculation inside the flow field and potentially mixing of both layers; or gathering and releasing particles which might lead to line defects.



By optimizing the geometry of each detail section in the different flow fields they become less susceptible for disturbances and thus to defects of the coating, which lead to minor product quality.

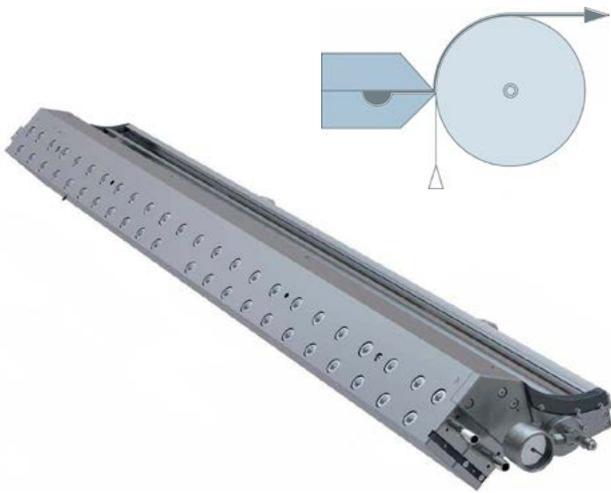
Photos courtesy by Dr. Peter M. Schweizer

SLOT DIES

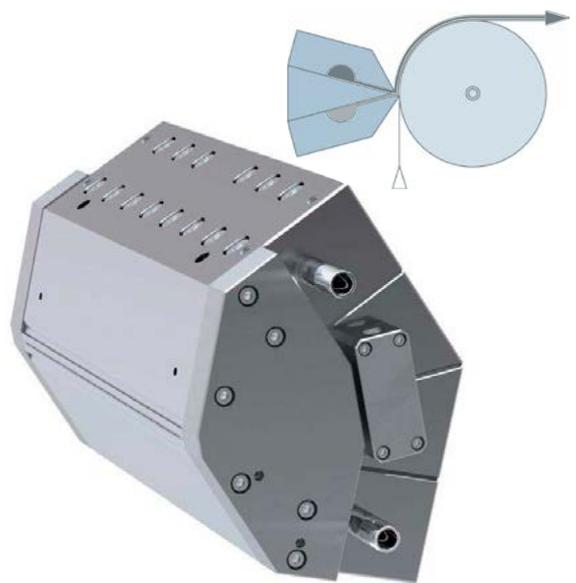
Of all the pre-metered coating methods, slot coating can be the most demanding of die design and precision fabrication. First, the internal manifold of the die must supply a uniformly-distributed flow to the coating transfer gap region. However, complex liquid rheology and/or significant flow effects may require the use of an optimized manifold design with varying slot length and cavity cross-section (coat-hanger design). Even with optimized design, excellent coating weight uniformity requires exacting slot depth uniformity. Achieving desired slot coating transfer flow is also challenging. Process-capable lip designs carried out with superb

straightness, uniform lip lands and well-defined, uniform lip corners are all required to maximize coating windows and to enhance coating robustness within these windows.

TSE is certainly up to this task. With unmatched fabrication precision, optimized design capability with advanced flow modelling, coating know-how and decades of supplying precision dies to the world's most demanding companies. Supplying dies that conquer challenging, demanding coating applications is our niche!



Single Layer Slot Die with Vacuum Box



Three Layer Slot Die

Range of Application (order of magnitude only)

– Viscosity range:	[mPas]	1–10'000
– Surface tension:	[mN/m]	–
– Coating speed:	[m/s]	0.01–10
– Wet thickness H_{wet} :	[μm]	> 5
– Dry thickness H^{dry} :	[μm]	< 1
– Number of layers:		1–\leq 3
– Minimum flow rate:	[cm^2/s]	–

CURTAIN SLOT DIES

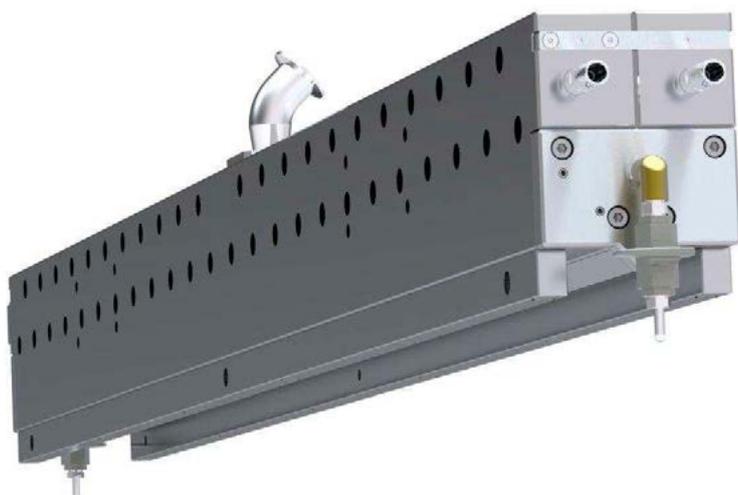
Slot Curtain coating is an attractive coating method because several major process advantages are achieved. These advantages include a potential for high speed coating, a significant coating robustness with respect to web disturbances, and a substantial tolerance for imprecision in the clearance between die and substrate.

The design and fabrication of the curtain slot die must be executed with high precision if excellent coating quality is to be achieved. For example, the slot die lip region must have an excellent surface finish. It should also be designed such that it resists irregular wetting along the lip. Furthermore, these lip features must be uniform across the die width. Finally, as with all premetered coaters, the production of a

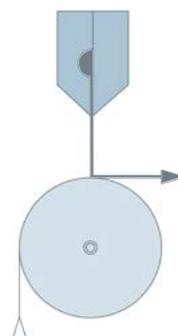
uniformly distributed flow via the internal flow manifold requires both optimal manifold design and excellent slot depth uniformity.

TSE has produced many successful curtain dies in both slot and slide die formats. TSE has also developed the essential supporting technologies and practical designs associated with capable curtain edge guides, baffles to remove the air boundary layer on the incoming web, coating initiation/termination functions and devices that protect the liquid curtain from the detrimental effects of air currents.

In view of this complete technology package, there is no question that TSE is the leading supplier of dies for successful curtain coating.



Single Layer Curtain Slot Die



Range of Application (order of magnitude only)

– Viscosity range:	[mPas]	10–5'000
– Surface tension:	[mN/m]	< 40
– Coating speed:	[m/s]	1–20
– Wet thickness H_{wet} :	[μm]	> 5
– Dry thickness H_{dry} :	[μm]	< 1
– Number of layers:		1–\leq 2
– Minimum flow rate:	[cm^2/s]	> 1.0

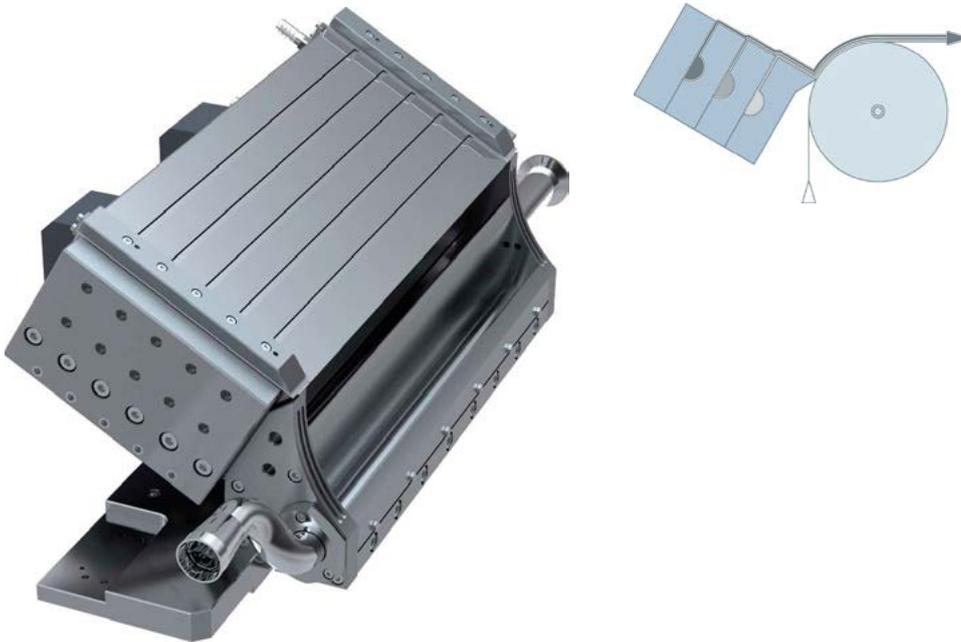
SLIDE DIES

Slide coating has been the multilayer workhorse for the photographic industry for many years and its use has been extended to other applications where excellent quality multilayer coatings are required. TSE has a long history of providing successful slide dies and slide coating stations to the world's most competitive coating companies.

For truly excellent coating quality, slide dies require a level of excellence in design and fabrication precision rivaled only by slot dies. The slide die lip region is critical. The die lip must have a capable shape, a superb surface finish, well defined corners and these features all must be uniform across the coating width. Furthermore, the lip must be extremely straight.

The geometry of the transition between the individual distribution slot exits and the slide surface is also critical in that it must allow disturbance-free introduction of the layer into the multilayer package flowing down the slide. Finally, as with all pre-metered coaters, the production of a uniformly distributed flow via the internal flow manifold requires both optimal manifold design and excellent slot depth uniformity.

The challenges in slide die optimal design and precision fabrication are considerable, but TSE has consistently demonstrated its expertise by providing world-class slide dies to its customers.



Five Layer Slide Bead Die with Vacuum Box

Range of Application (order of magnitude only)

– Viscosity range:	[mPas]	1–1'000
– Surface tension:	[mN/m]	–
– Coating speed:	[m/s]	1–10
– Wet thickness H_{wet} :	[µm]	> 50
– Dry thickness H_{dry} :	[µm]	< 1
– Number of layers:		1–> 10
– Minimum flow rate:	[cm²/s]	–

CURTAIN SLIDE DIES

Curtain coating in the slide format is being adopted increasingly by large segments of the coating industry because of its high productivity, multilayer capabilities and robustness with respect to web disturbances. The curtain coating concept is simple enough to allow a liquid layer falling from a die edge to impinge on a moving web. However, the realization of excellent coating quality with this method demands optimal die design coupled with precision fabrication. These are TSE's strengths.

As with all pre-metered coaters, the production of a uniformly distributed flow via the internal flow manifold requires both optimal manifold design and excellent slot depth uniformity. The curtain lip also must be designed to

resist irregular wetting and the teapot effect. Furthermore, lip fabrication uniformity is essential for excellent coating uniformity.

TSE has produced successful slide curtain dies for many years and for a wide variety of customers. During this time, TSE has developed the essential supporting technologies and designs associated with capable curtain edge guides, baffles to remove the air boundary layer on the incoming web, coating initiation/ termination functions and devices that protect the liquid curtain from the detrimental effects of air currents.

In short, TSE is the leading supplier of slide curtain dies with this world-class capability.



Four Layer Curtain Slide Die with TSE Troller patented porous-glass Curtain Edge Guides

Range of Application (order of magnitude only)

– Viscosity range:	[mPas]	10–5'000
– Surface tension:	[mN/m]	<40
– Coating speed:	[m/s]	1–20
– Wet thickness H_{wet} :	[μm]	>5
– Dry thickness H_{dry} :	[μm]	<1
– Number of layers:		1→10
– Minimum flow rate:	[cm²/s]	1.0

TSE-TABLECOATER FOR BATCH-WISE COATING

For several years, new products and applications in the fields of electronics are being developed, which raise particular demands even on the application technique. The specialty here is to apply very thin layers in the dry thickness range of approximately 50 to 200 nanometres on various substrates. Ideally this should be done with a suitable application method for an economical mass production.

The development of conventional coatings in areas such as Paper or adhesive so far allowed the application by hand in the laboratory, since the later transfer was tested in a production. Even the most economical use of the coating materials was not necessary because the liquids commonly existed in sufficient quantity.

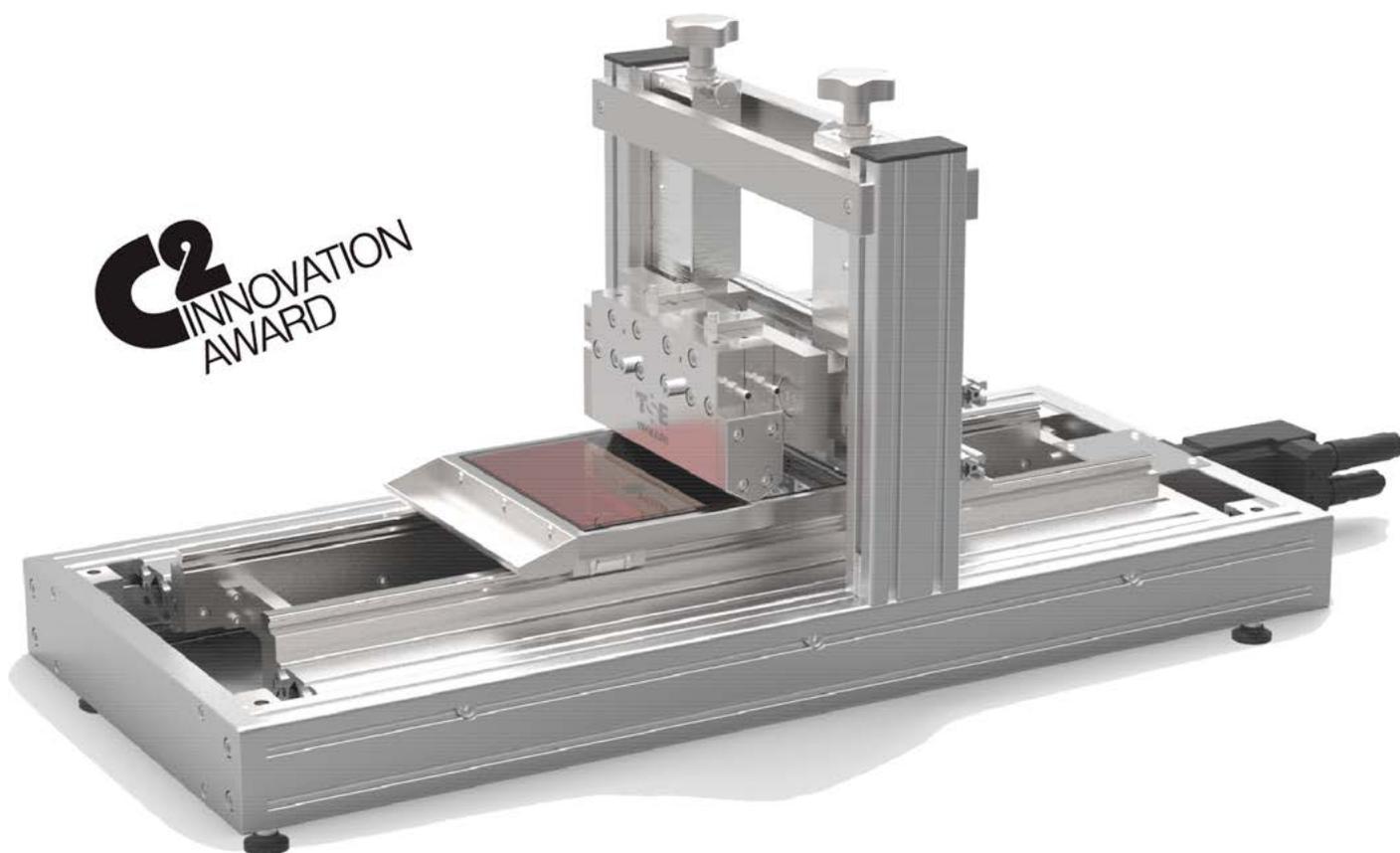
When designing new products in the field of flexible electronics (with the examples of organic photovoltaic (OPV) and organic LED's (OLED)), the appropriate components of the coating liquids are often only available in very limited mass and correspondingly expensive.

Thus, the filling volume of the entire system is very important to allow for economic development. Also, the application of a few micrometers thin, uniform layer with a simple manual procedure is not possible. In order to ensure the scale-up from the laboratory in a subsequent "Roll-to-Roll" process the same application process should be used from the beginning, as it is most promising for a later production. The pumping system must be appropriate also to deliver the liquid in the required, very low quantity.

This requires bridging the gap between the lab-scale of the development laboratory on one hand and industrialized, well proven coating processes on the other hand.

On the occasion of the ICE-2011 in Munich, the new TSE-TableCoater was decorated with the C2-Innovation Award among around 40 competitors.

The new TSE-TableCoater including a single and a dual layer slot die is available for rent for first feasibility trials. Please contact us for a quotation.



TSE-TableCoater with single layer slot die

Often only a few samples of a new development step are sufficient in order to analyze the functionality, efficiency and other features. Nevertheless the conditions of the experimental setup should be comparable with a later production runs, to minimize risks.

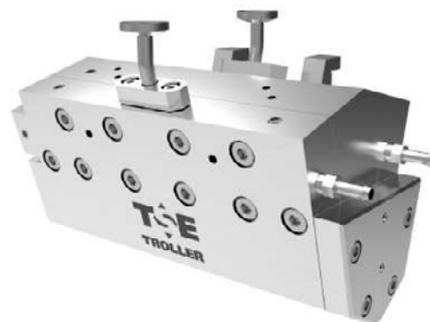
For this purpose TSE has developed a modular coating system which allows to coat onto individual "sheets" with a slot die in the lab-scale. The TSE-TableCoater can be characterized by the following key features:

- High precision slot coating method, scalable from lab to industrial production
- Variable size of the substrates to be coated made of glass, plastic, paper or metal foil
- High precision height adjustment
- Skip-Out function available

- Minimized dead volume in the slot die, thus cost-effective development of new products
- Generic or custom-designed slot dies with customer specific coating width
- Modular design with multiple options
- Slot dies manufactured of various acid-resistant materials, with heating capability
- Large operating window - "from water to honey"
- For water- and solvent-based systems, also for solvent-free liquids
- Dry thickness of 20nm to 500 micron
- Wet thickness below 5 micron possible
- Speeds between 0.1 and 6m/min
- Customized fluid delivery system
- Transferable to "Roll-to-Roll" – Process
- Operating software



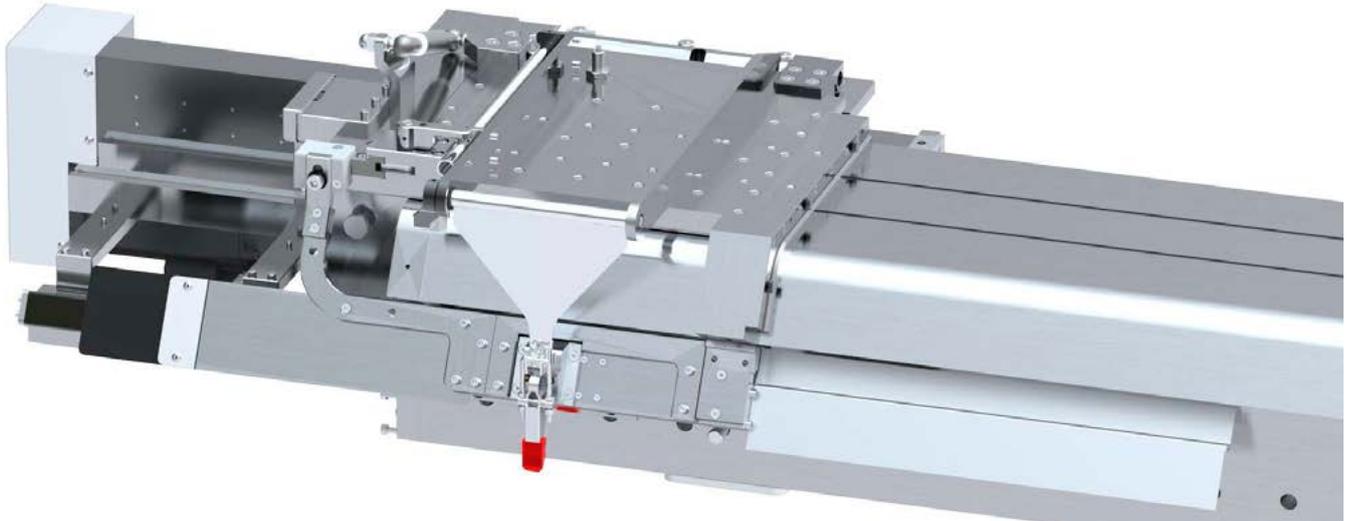
Option with dual layer slot die, vacuum clamping table, flow box, enclosure and base frame



SEVERAL OPTIONS ARE ALSO AVAILABLE:

- Dual and triple layer slot dies
- Alternate die materials (PEEK, Titan, Hastelloy, Langalloy ...)
- Vacuum clamping table
- Heating provision for table
- Servo driven height adjustment
- Automated coating gap calibration
- Flow box / clean room
- Integration in Glove- Box
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MOTORIZED VARIABLE COATING WIDTH (MVCW)



MVCW on a dual layer curtain coating die

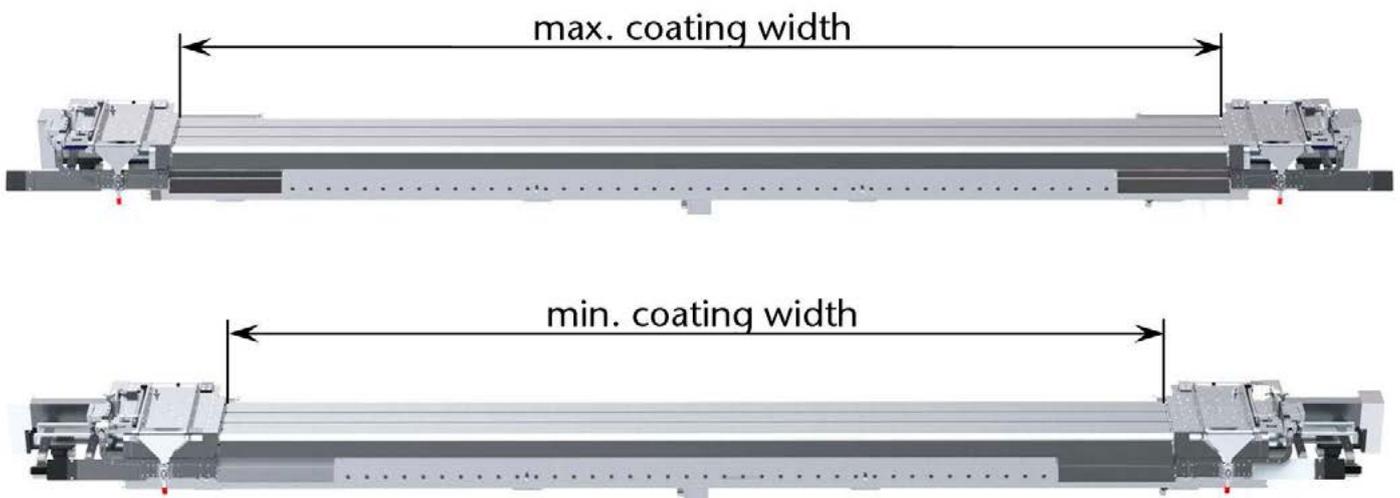
Driven by market demand for a wide product assortment as well as smaller production lots, companies are more and more forced to change the production width very frequently. Due to the long non-operational periods during width changes, the converter line efficiency becomes very low while on the other hand our customers have to increase their plant efficiency continuously in order to cope with the cost pressure.

To have an option available for our customers with curtain coating slide dies, TSE has developed the MVCW system, which can adjust the coating width motorized, continuously and fully automatic. The different coating widths can be set by the same system and the big number of parts being necessary for conventional width adjustments

can be covered by the MVCW, thus making the spare part management easier and less costly. The changeover time could be reduced at one of our customer plant from 4 hours to only 12 minutes with the MVCW system.

Furthermore, the risk of damaging parts due to improper handling could be eliminated. An integrated flushing system is cleaning the cavity deckles during the process of changing the width. The movements of the MVCW are pneumatic and motorized while sensors are controlling the movements.

The development team of TSE Troller AG has designed and industrialized this system in close collaboration with its customers.



DEVELOPMENT COATER

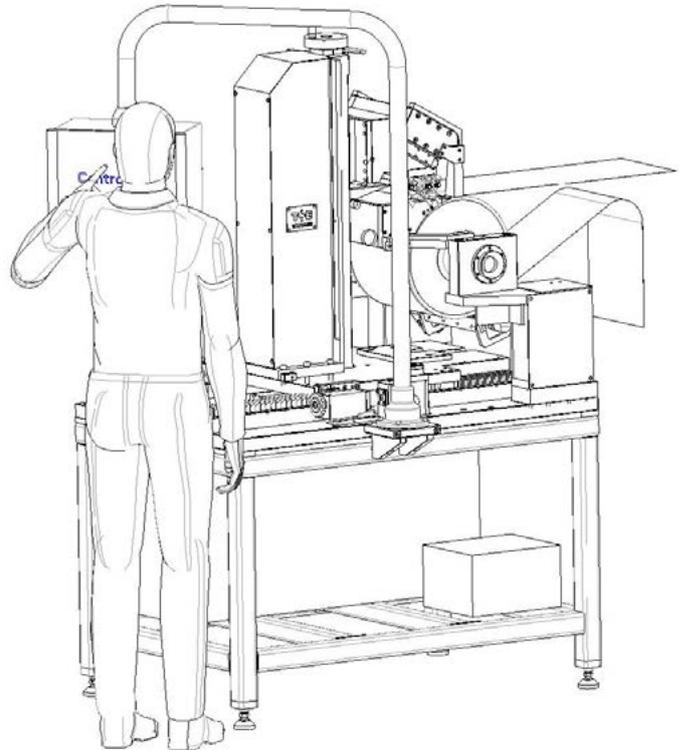
The TSE Troller Development Coater is an extremely valuable tool in the hands of a dynamic production or research organization. Its use can jump-start a concurrent product-process development, facilitate continuous coating process improvement and lead to enhanced product quality.

Our Development Coater is configured from an equipment kernel that includes a driven roll, squeegee-collection system and positioning system. Various modules for the different pre-metered coating methods such as: slide-bead, slide-curtain, slot-bead, and slot-curtain can be attached. With any coating configuration, the resulting assembly is a compact, table-top device and yet its capabilities are extensive. For such a small, economical device, the potential for fundamental process understanding and therefore process improvement is truly significant.

Versatility is the watchword of the development coater. Its compact design means that it can be used in almost any location with minimal space and support systems. It can be used as a stand-alone system or can be docked with existing web line facilities in order to coat web. Its modular design is the essence of flexibility with change-over requiring only a modest effort.

Considering the process understanding that can be achieved, the development coater is truly economical. In the stand-alone configuration, few supporting systems and personnel are required and the device docks easily to existing systems for completing the coating process. The device design is arranged to achieve minimal costs. Only coating modules of interest need to be purchased and other modules can be added later if needed. Finally, many of the more precisely made components can be assembled

into different modules; for example, slide coating plates can be used in either slide bead or slide curtain die mode and the slot die clamshell assembly can be used in either slot-bead or slot-curtain modules.



Development Coater equipped with Curtain Slide Die and TSE- Curtain Edge Guides

Each of the modules can be configured to include precisely-adjustable coating parameters as well as replaceable components where desired. Slot-die modules, for example, can include adjustable coating gap and angle of attack and the die can be supplied with replaceable lips and shimming plates for different slot depths. Other coating methods have comparable parameters of adjustment and can be supplied with replaceable components too.

WHAT TYPE OF COMPANIES CAN BENEFIT FROM THIS COATING DEVELOPMENT TOOL?

- Companies or other groups that are getting started with coating, having limited coating experience outside of their legacy method, or have limited facilities and other resources. For them the Development Coater is an economical way to quickly get started in understanding the different pre-metered coating processes.
- Companies undergoing concurrent process development and coated product. The use of the Development Coater can quickly accomplish much of the early scouting work and thereby jump-start the program.
- Experienced coating companies. This coating device can complement existing laboratory facilities such that overall efficiency is improved. It provides an efficient and capable method to screen coating batches prior to committing to large scale production. It can serve as an excellent training aid for operators and can be used to investigate coating defects.

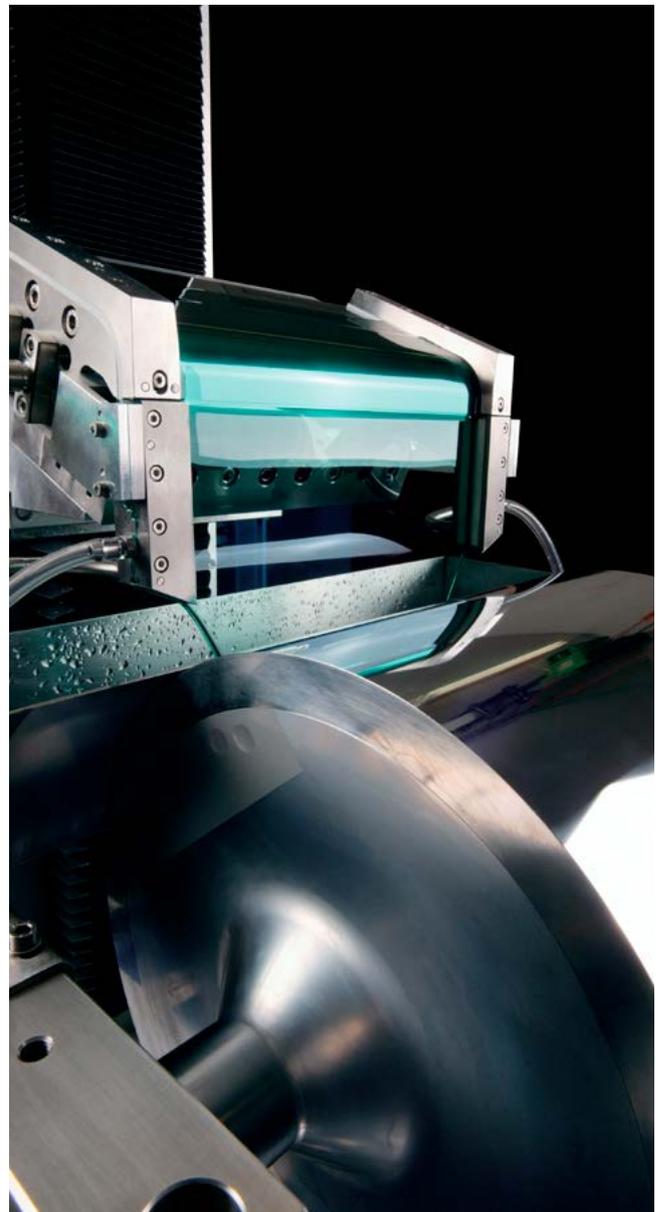
RENTAL CONDITIONS FOR DEVELOPMENT COATER

The Development Coater or coating dies can be rented from TSE Troller for the customers internal developments. Several coating dies (single and dual layer slot die, multilayer slide and slide curtain die) are at your disposal. All coating dies fitting to the Development Coater have a coating width of 260mm. Other dies of alternative width are available as well.

The development coater can either be used in a stand-alone setup in order to examine the process itself but also at one end of a pilot coating line in order to coat onto the running substrate.

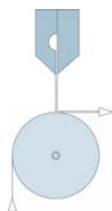
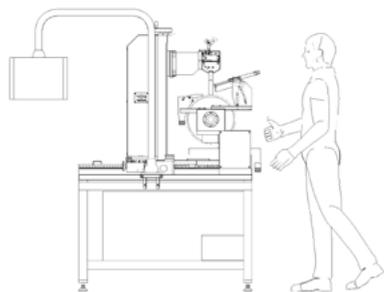
The total rental cost for the trial equipment include the rental fee (only test days), the base set-up fee and the transportation cost for the equipment and the working time of the TSE Troller Engineer, plus travel costs. In case of a die order the rental fee will be refunded. Please contact us for a quotation.

The customer will bear the cost for repair in case of any damages.



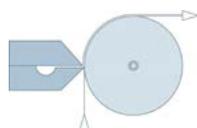
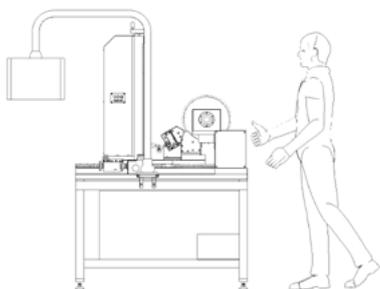
Development Coater equipped with Curtain Slide Die and TSE-Curtain Edge Guides

DIFFERENT COATING MODES ON THE DEVELOPMENT COATER



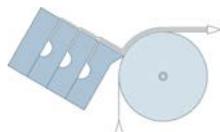
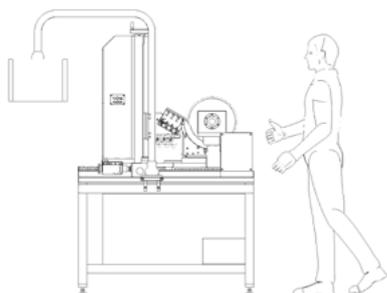
Slot Curtain Mode

Viscosity range:	[mPas]	10–5'000
Coating speed:	[m/min]	60–1'200
Wet thickness:	[µm]:	>5



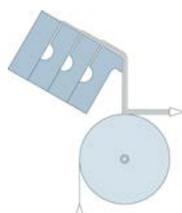
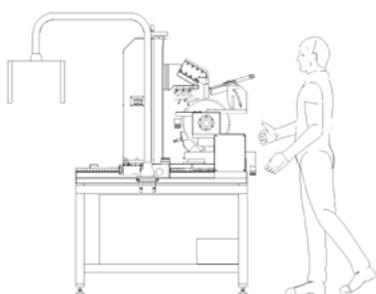
Slot Bead Mode

Viscosity range:	[mPas]	1–10'000
Coating speed:	[m/min]	1–600
Wet thickness:	[µm]:	>5



Slide Bead Mode

Viscosity range:	[mPas]	1–1'000
Coating speed:	[m/min]	60–600
Wet thickness:	[µm]:	>50 (total)



Slide Curtain Mode

Viscosity range:	[mPas]	10–5'000
Coating speed:	[m/min]	60–1'200
Wet thickness:	[µm]:	>5 (total)



**TSE TROLLER is capable to manufacture more than 10
layer slide curtain dies up to a width of 4650 mm with
a slot precision less than a micron.**

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