Advances In Web Coating Process Technology

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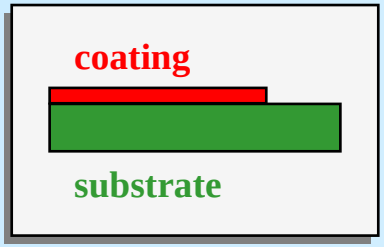
Topics

- **Web coating process technology development**
- **Initial coating technology development**
- **Currently available advanced technologies**
- **Future technology**

Definition of Coating

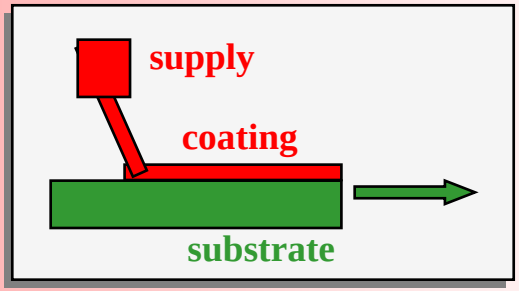
Coating



To replace the air at the surface of a substrate with one or more layers of material to give a new structure with different properties.

Liquid Film Coating

The applied material is liquid and replaces the gas adjacent to a solid surface (usually the gas is air but can be another gas, e.g., nitrogen).



Vapor Deposition

The application of a material from the vapor state to a surface producing a new layer.

History of Development

- **Block printing China ~ 800AD**
- **Guttenberg printing press Germany 1450**
- **Fourdrinier machine 1799**
- **Roll Coating ~ 1850**

- **Is old process which is continually evolving**
- **Technology development continuing**
- **However, time scale is much longer than for introduction**
- **May take 10 years or more for wide spread acceptance and implementation**

Stages of Technology Development

1. Initial applicator concepts 1850 to ~1960
2. Dryer Development 1970 to present
3. Fundamental Studies ~1975 to -present
4. Precision Premetered multilayer coating methods 1975 to present
5. Increased focus on overall coater systems. 1995
6. Wider range of products coated 2000

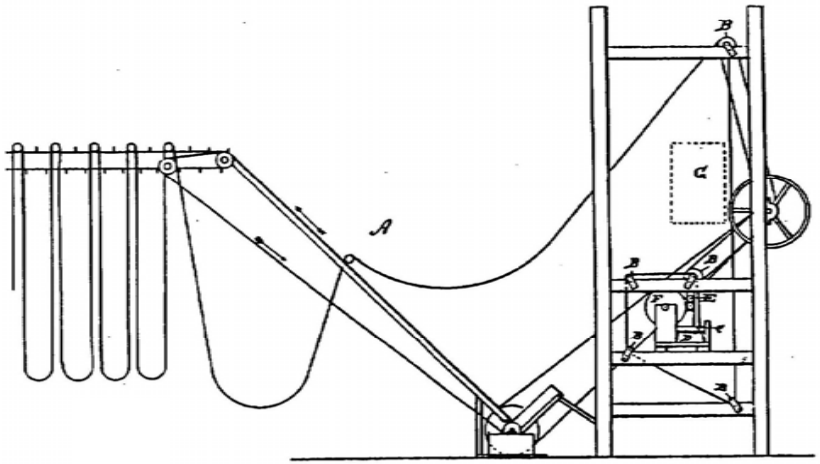
Coating Process Evolution

(No Model.)

W. H. WALKER & G. EASTMAN.

PROCESS OF COATING PHOTOGRAPHIC PAPER.

No. 370,110. Patented Sept. 20, 1887.



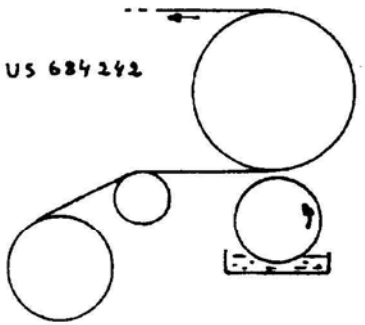
Festoon Dryer

Dip Coater

Coating Method Evolution

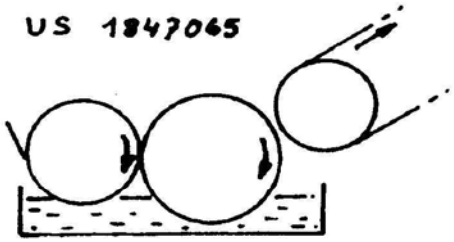
- **First patents**

Mason and Scott, US 684,242 (1901)



TWO-ROLL REVERSE
FOR PAPER COATING

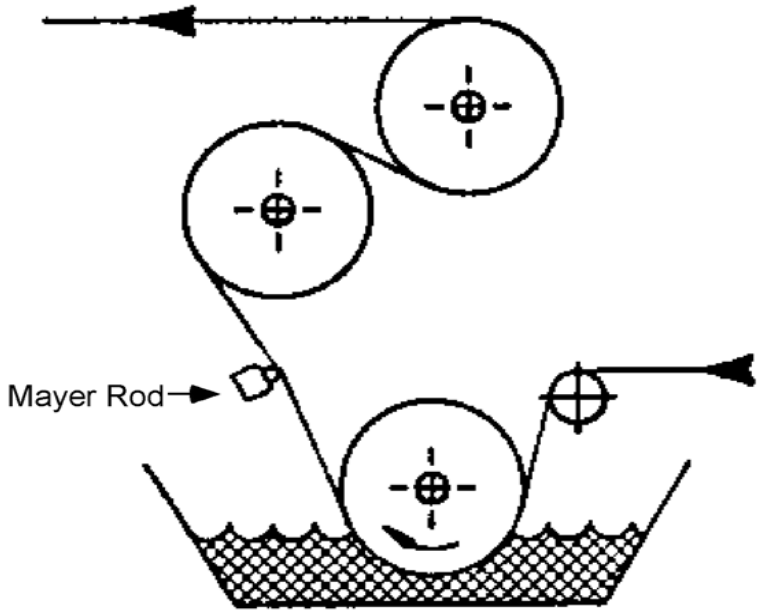
Munch, US 1,847,065 (1927)



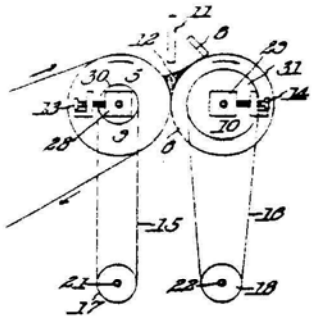
THREE-ROLL REVERSE SYSTEM
FOR PAPER COATING

Early Patents

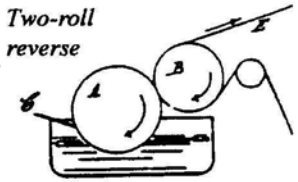
- **Mayer Rod 1904**

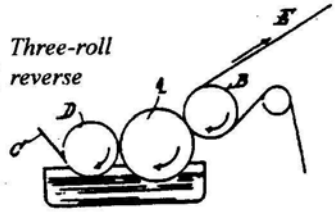


On Going Patents



Bradner, US 1,838,358 (1931)

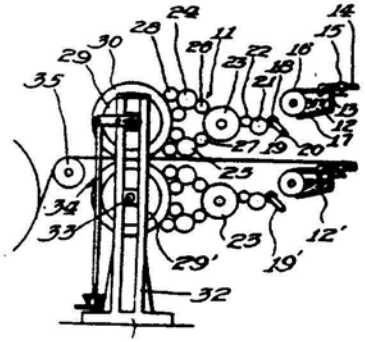




Munch, US 1,847,065 (1932)

Massey, US 1,921,368 (1930)

Multi-roll transfer coater
Many forward roll film splits



Dryer Development

- **Drying capacity was major rate limiting factor**
  - Could not dry at coater high flow rates
  - Operating conditions were comprise not best of coating
  - Limiting step in process
- **Low rates gave long dryer difficult to run**
  - Web stability
  - Web contact with rolls
  - Non-uniform drying
- **Low rates lead to long dryers**

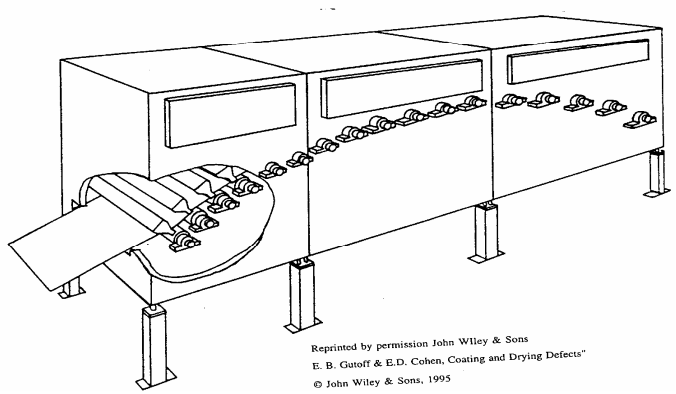
High Rate Impingement Dryer

- **Dryer Innovation 1972**
- **T. A. Gardiner showed air boundary layer**
  - Rate limiting
  - Could be broken-up without disturbing coating
  - Designed new nozzles
  - Lead to high rate dryers
- **Dryer no longer rate limiting**
- **Lead to floater dryers**
- **Examples of dryer efficiencies**

DRYER TYPE	h, BTU/ft2-HR-°F
Festoon dryers	1-3
Single side impingement nozzles	10-30
Floaters	20-60
Hybrid	60+

Impingement Dryer Configurations

IDLER ROLL DRYER



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E. B. Gutoff & E.D. Cohen, Coating and Drying Defects"
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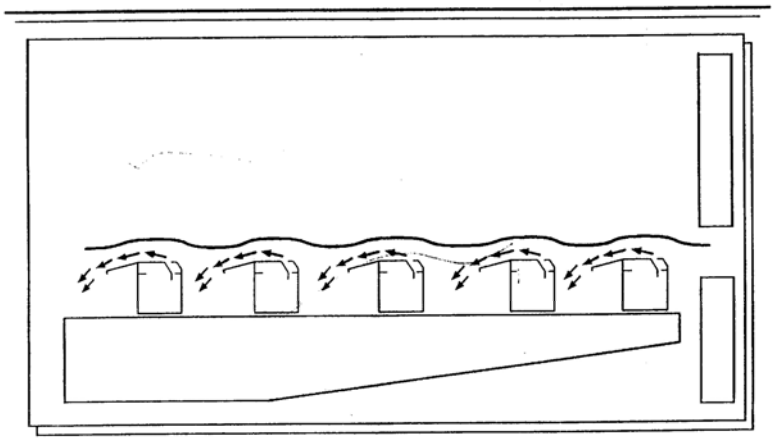
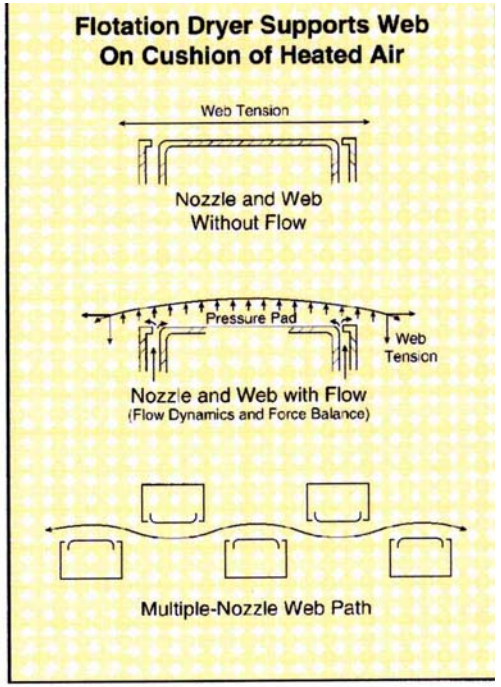
Single Side Airfoil





Current Major Technology Advances

- **Continuous improvement old coating techniques**
  - Higher speeds, improve fabrication, lower cost
  - More coating weight uniformity better quality
  - Serve specialized needs
  - Give process much more flexibility
  - Still viable coating techniques

Comparison of Older Coating Methods

Coating Method	Viscosity range, cp Wet Thickness .mic Line Speed. Fpm Uniformity, %	Advantages	Disadvantages
Gravure, Offset	V 20-13000 W 3-206 L 10-1000 U 2	Low thickness Pattern coat High speed	Cell pattern in coating Not for high thickness Gravure cylinder wear Low line speed
Gravure, Direct	V 1-500 W 3-65 L 25-2300 U 2	Low thickness Pattern coat Coat different webs	Cell pattern in coating Not for high thickness Gravure cylinder wear
Mayer Rod	V 50-1000 W 4-80 L 10-1000 U 10	Low cost, Available Simple process Easy thickness change Good technology base	Low solids & viscosity Scratches Low speed
Forward Roll	V 20-2000 W 10-200 L 100-1500 U 10	Simple to operate Relatively low cost	ribbing defect lower line speeds viscosity latitude
Reverse Roll	V 200-50000 W 14-450 L 20-1700 U 2	Thickness control high speed viscosity range quality	High equipment cost Precision construction Maintenance More technology to operate
Air Knife	V 1-500 W .1-200 L 40-400 U 5	Low thickness Good coverage Thickness easy to change versatile	Narrow speed range Low viscosity & solids Noise, misting contamination
Dip	V 40-1500 W 10-150 L 45-600 U 10	Relatively Inexpensive Saturate web Coat both sides	low viscosity low line speeds low coating weight Limited product use

Fundamental Understanding of Coating process

- **Understanding of fluid flow in coater**
  - Basic Mechanisms defined
  - Computer models
    - **Simulate coating flow**
    - **to customize designs**
  - Improved design of applicators
  - Understanding of defect mechanisms
- **Modeling Technology readily available**
- **No one method is optimum for all situations**
- **Need multiple methods**

Die design for coating flows

Sandia National Laboratories

Structural Dynamics and Vibration Control Department

OBJECTIVE FUNCTION: Minimize flow nonuniformity across the slot outlet

CONSTRAINTS:

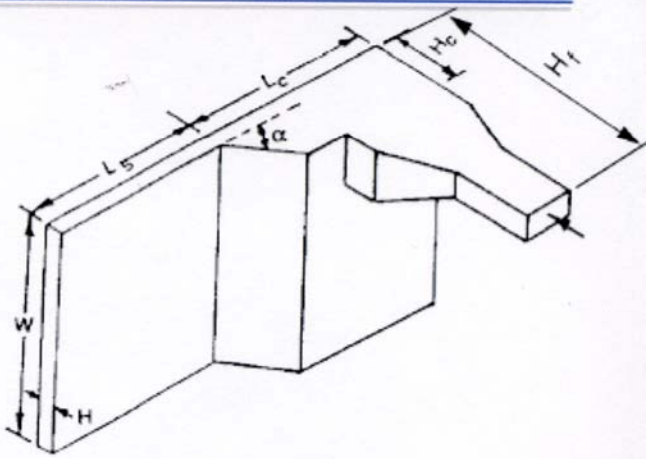
Max. inlet pressure ($P_{max} \leq 2100$)

Avg. fluid residence time ($t_{rt} \leq 325$)

GEOMETRIC DESIGN VARIABLES:

L_s, H_s, α, L_c, H_c, H_f

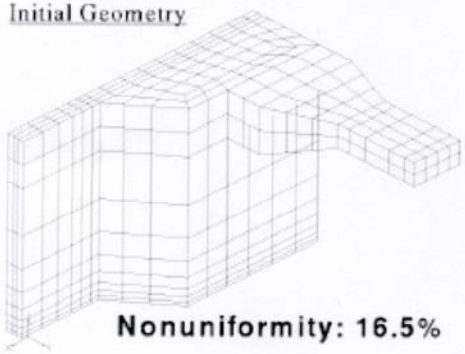
Slot width, W, is held constant.



Preliminary Optimization Results:

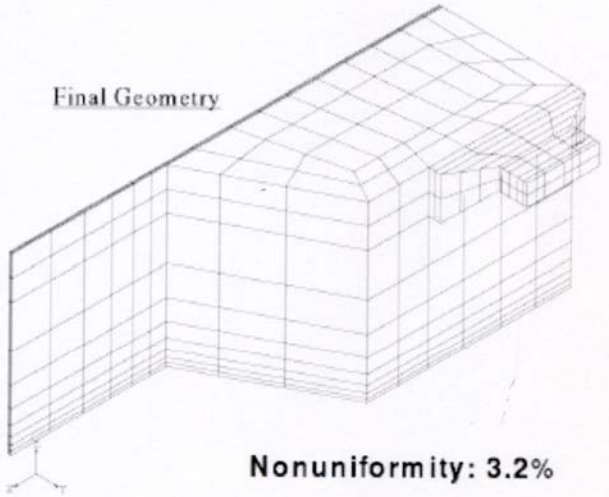
(follow-on studies to be part of proposed coatings consortium)

Initial Geometry



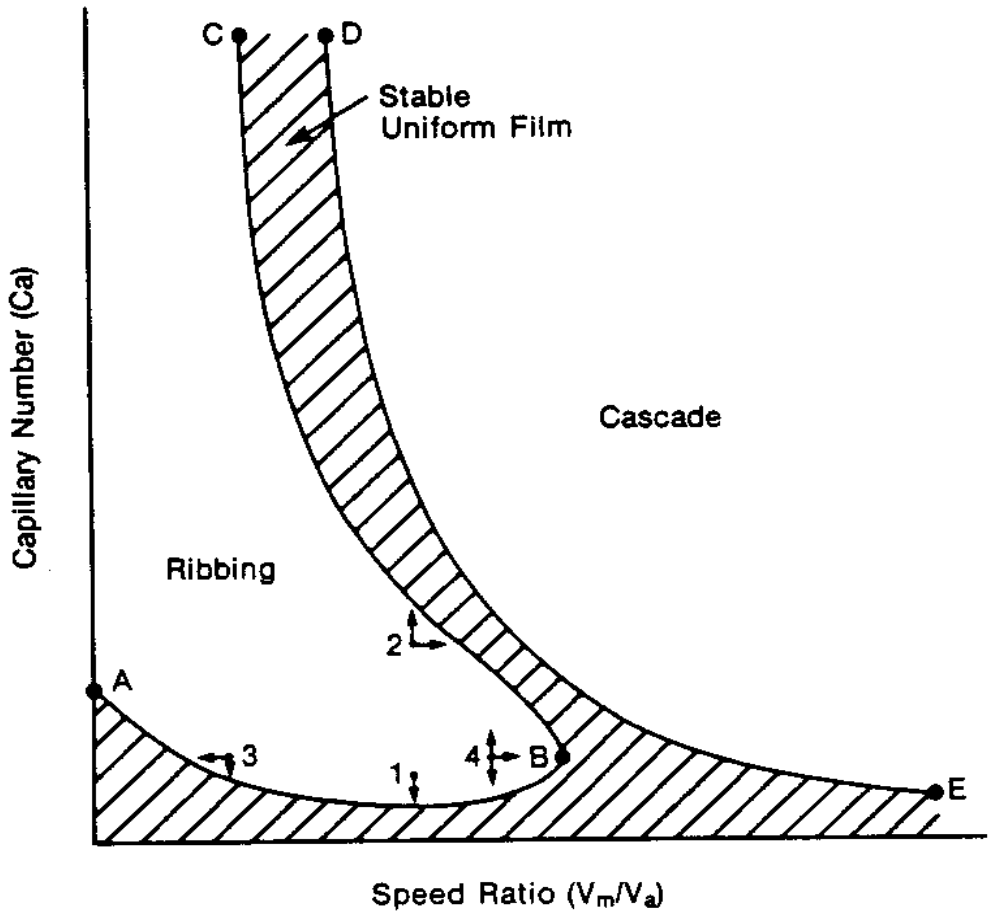
Nonuniformity: 16.5%

Final Geometry



Nonuniformity: 3.2%

GENERIC OPERABILITY DIAGRAM



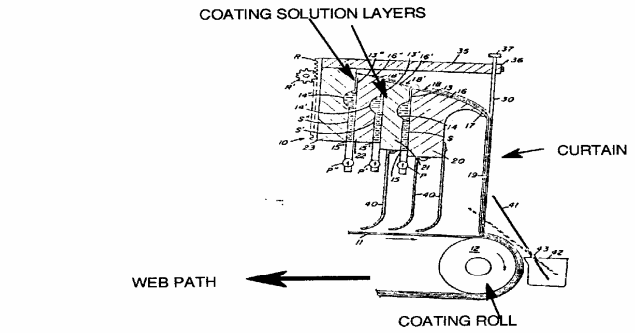
Coating Applicator Advances

- **Premetered multilayer applicators**
  - Slot die, slide, curtain
  - Offer Many advantages versus roll coating
  - Significant Improvement in applicator design, quality & cost
  - Wider range
  - Vendors use modeling technology to design
    - **Essentially custom deigns**
- **Advances in metal fabrication and metrology**
  - Increased hardware precision for better quality
  - Wider applicators
  - Lower costs

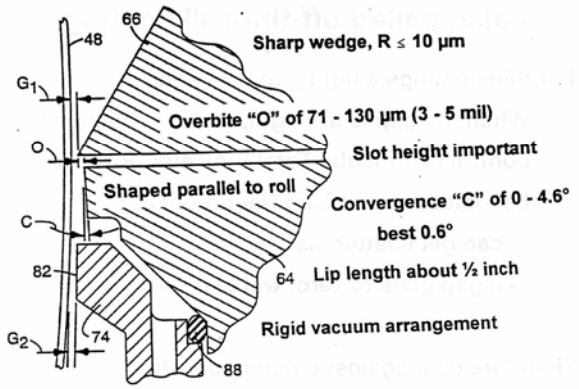
Key Technology Patents

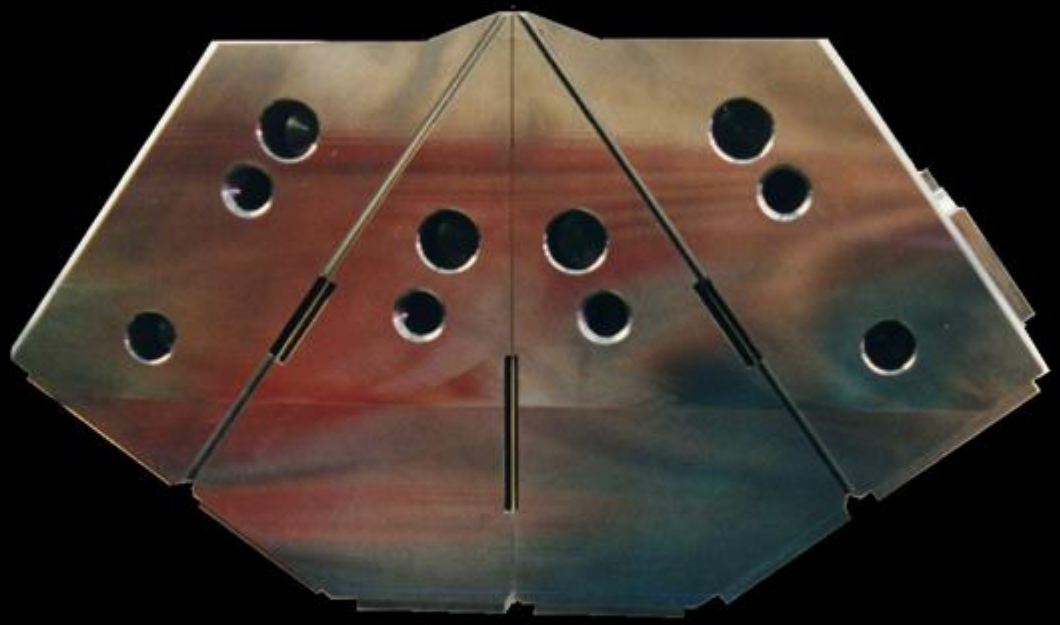
Hughes, D.J. USP 3,508,947, 4/28/70 MAIER, G., BROWN, O. USP 5,741, 549 4/21/98

MULTILAYER CURTAIN COATER



A SLOT DIE PATENTED BY 3M





MULTI-LAYER SLOT DIE

Curtain-Coating

Pressure sensitive adhesive 1000 m/min

Slot die Advances

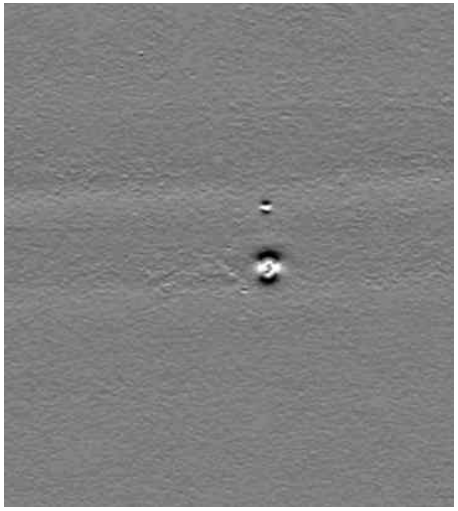
- **Support systems**
  - Pumps, flow meters, deaeators
- **Result**
  - Premetered coating technique
    - **Has several advantages**
    - **can be implemented by all**
      - New coaters or retrofits

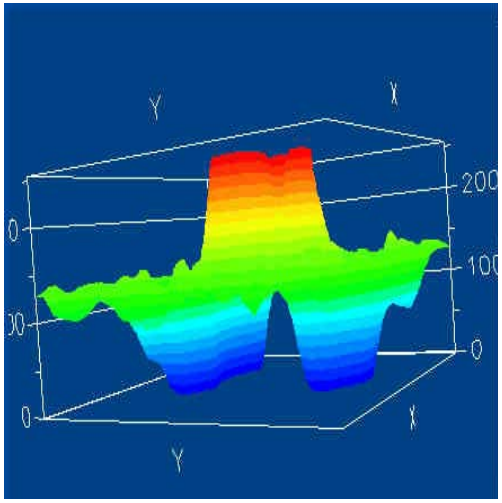
On-line Quality Measurement Systems

- **Sampling Off-line standard technique**
- **Advances in Electronics, computers, programming developed new on-line techniques**
  - Coating weight,
  - Defect surface inspection systems
  - Viscosity
- **Give rapid accurate results**
- **Can be used as control loops**
- **Are more reliable then humans**
- **Easily justified by defect and downtime reduction**
- **Will be essential for all coaters**

On-line Defect Detected

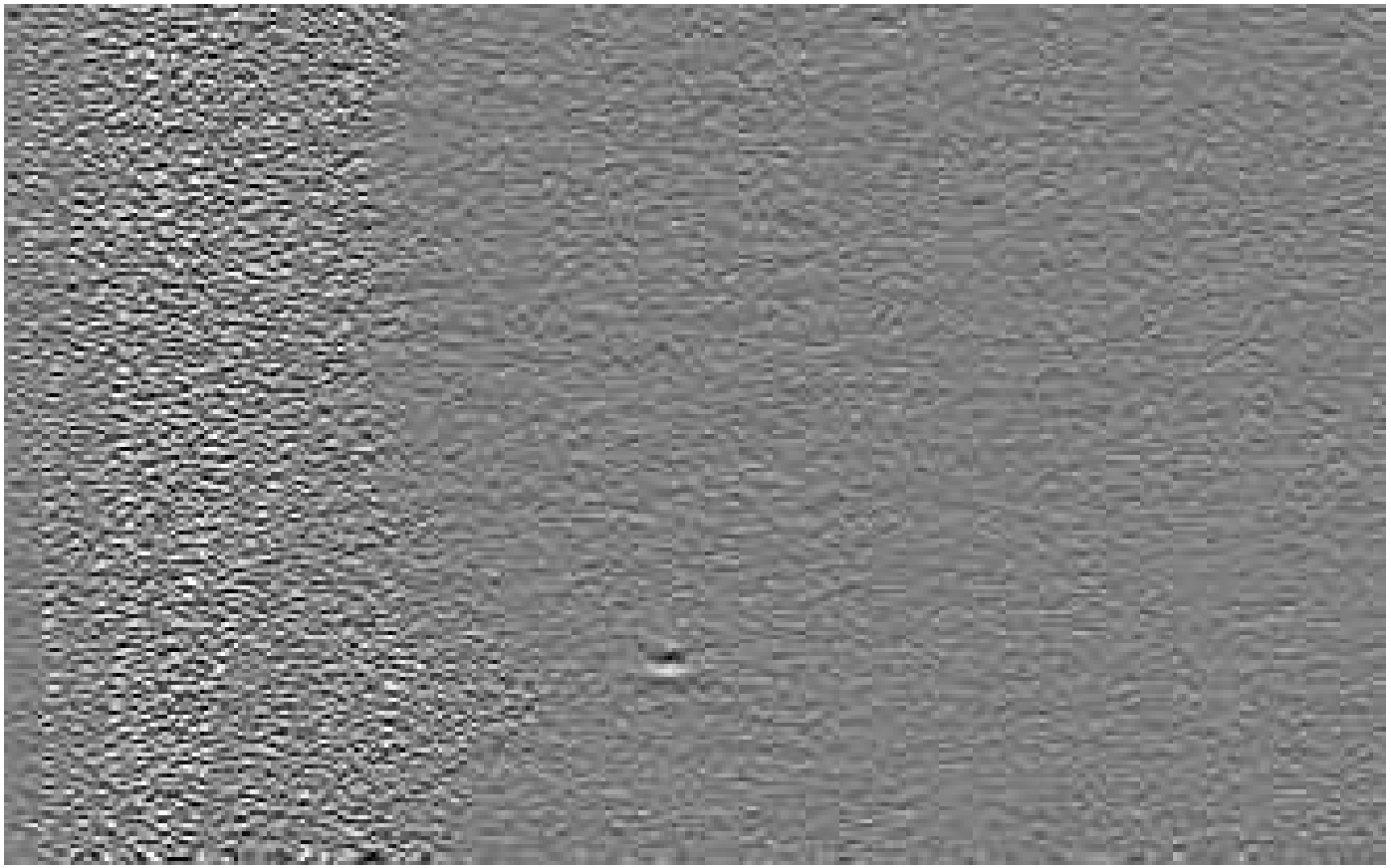
- **Holes**



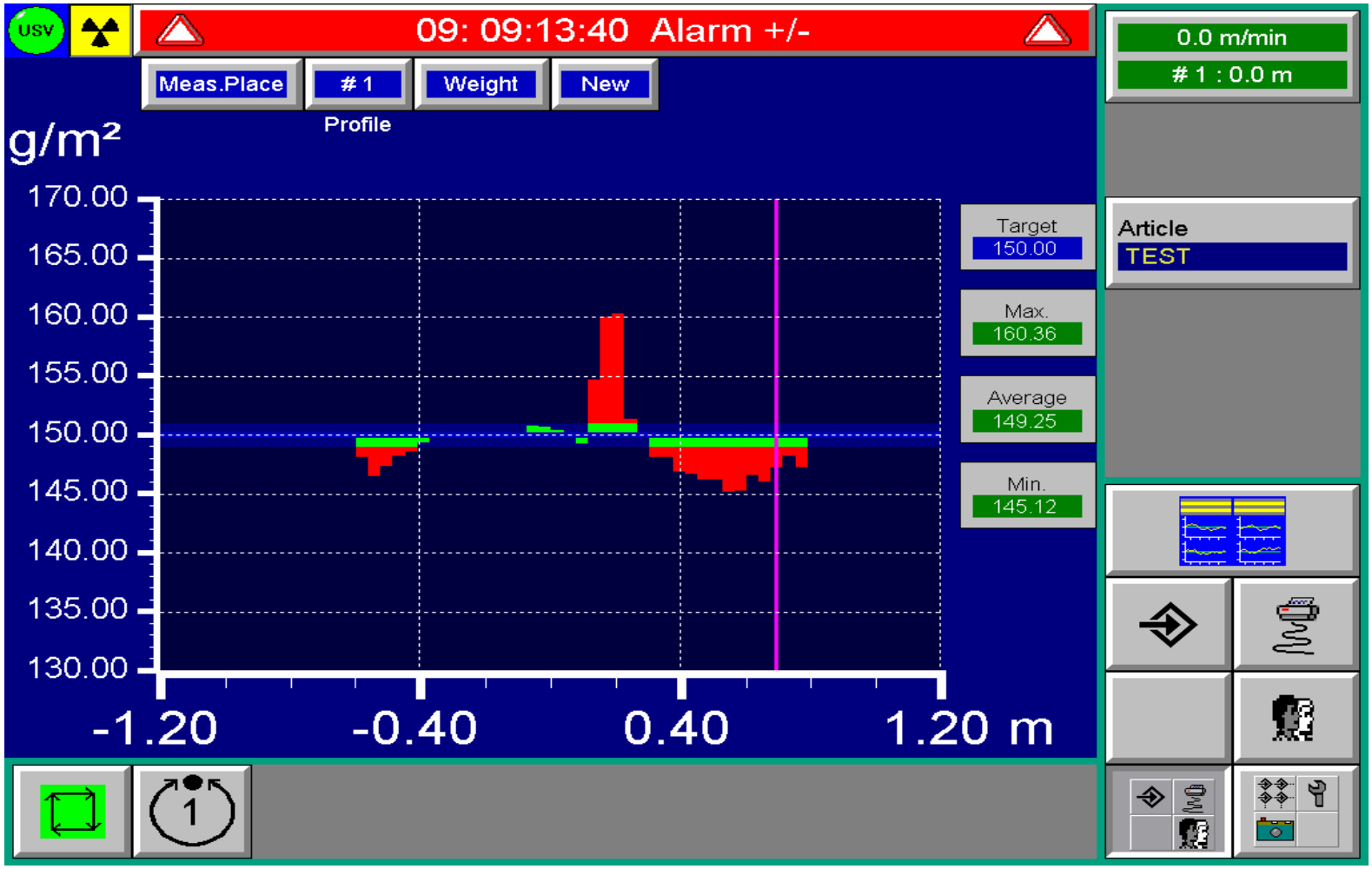


Courtesy Isra Vision Systems

Orange Peel

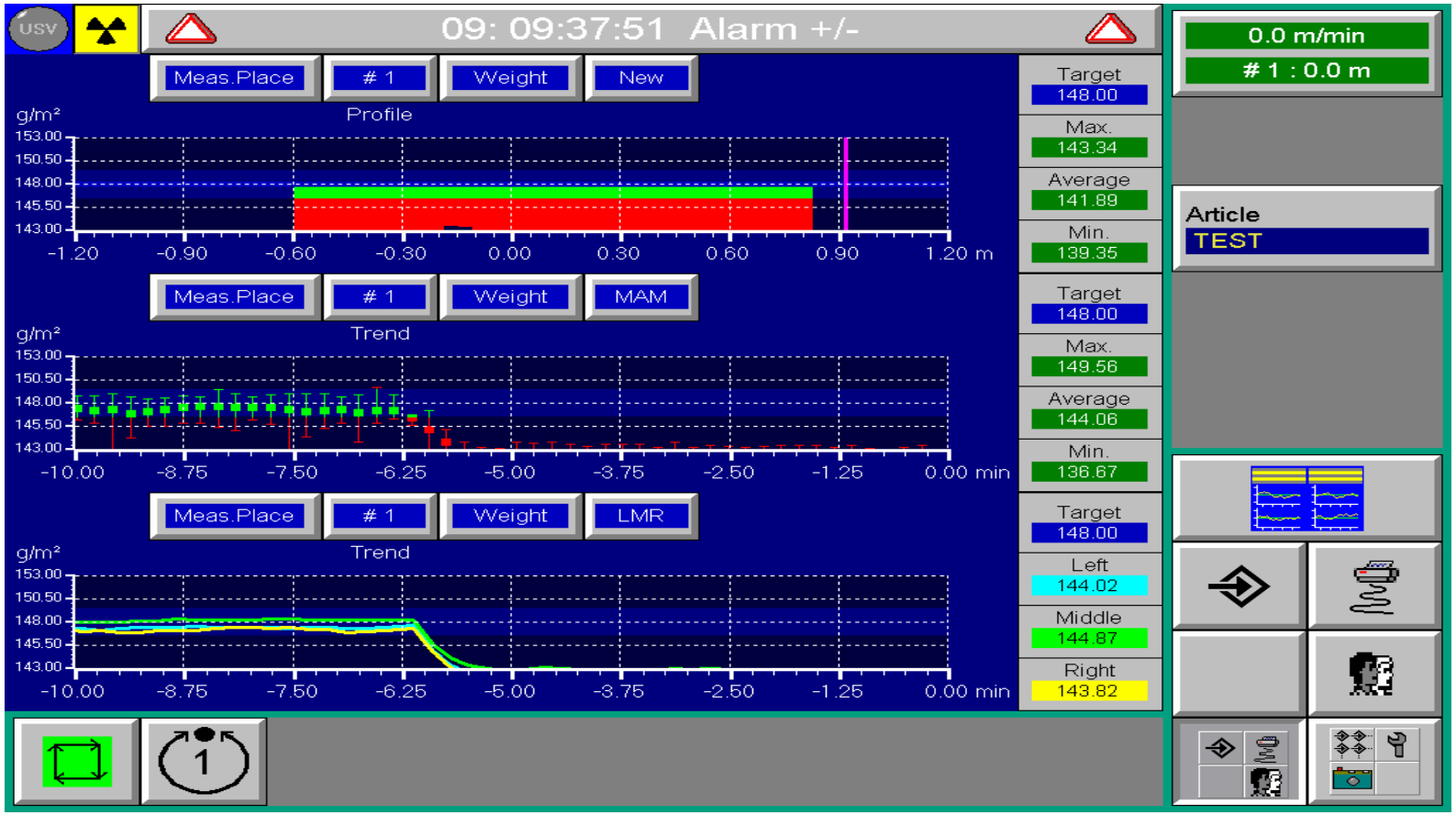


Cross Direction (CD) Profile



Courtesy Mahlo

CD Profile & MD Trends



Courtesy Mahlo

Rapid Change Coating Station
Cartridge Coaters

- **Current standard coating station**
  - Designed for one method
  - New method can be added
    - **Time consuming**
    - **May not be able to get precision & accuracy needed**
- **Cartridge coating station**
- **Designed for rapid change**
- **Each method in cartridge**
- **Can have several cartridges**
- **Fast, tool less changeover of coating methods 5 min**
- **Utility connections are accomplished automatically**

Cartridge Coaters

Increased focus on Coater Support Equipment

Surface treatment
- flame
- corona discharge
- plasma
- web cleaner
- static control

Solution Mixing
- high shear
- low shear
- cleaning equipment
- filtration

Solution delivery
- filtration
- debubbling
- pumping
- temp. control
- viscosity control
- In-line
- cleaning

Support station
- precision applicator settings
- vibration isolation
- rigidity
- cartridge

On-line measurement
- coating weight
- defect detection
- viscosity

Coater room
- temperature control
- relative humidity control
- airflow
- particulate control

Coater Rolls and Bearings
- roll surface
- unif or mity & balance
- bearings type lubricant

Personnel Training

Procedures
- equipment
- testing

ProcessInstrumentation
- line speed / web tension
- dryer H&V control
- drypoint detection

Contamination control
- dryer air filtration
- coater air filtration

Quality Control
- S.P.C.
- 6-sigma
- test methods

DataManagement
- computer data acquisition
- statistical Analysis
- defect database
- remote access

Roll Storage
- environmental control
- contamination control

bold are general equipment categories
normal are specific equipment examples

High Quality Laboratory Coater

- **Laboratory coating have had poor technology**
- **One of the weak areas in the coating process**

- **New Coating Technology for Lab & Scale-up coating**
  - Replacing hand coatings
  - Automated can control coating & drying
  - Improved quality
  - Cost effective
- **Can produce customer quality**

Courtesy Werner Mathis USA

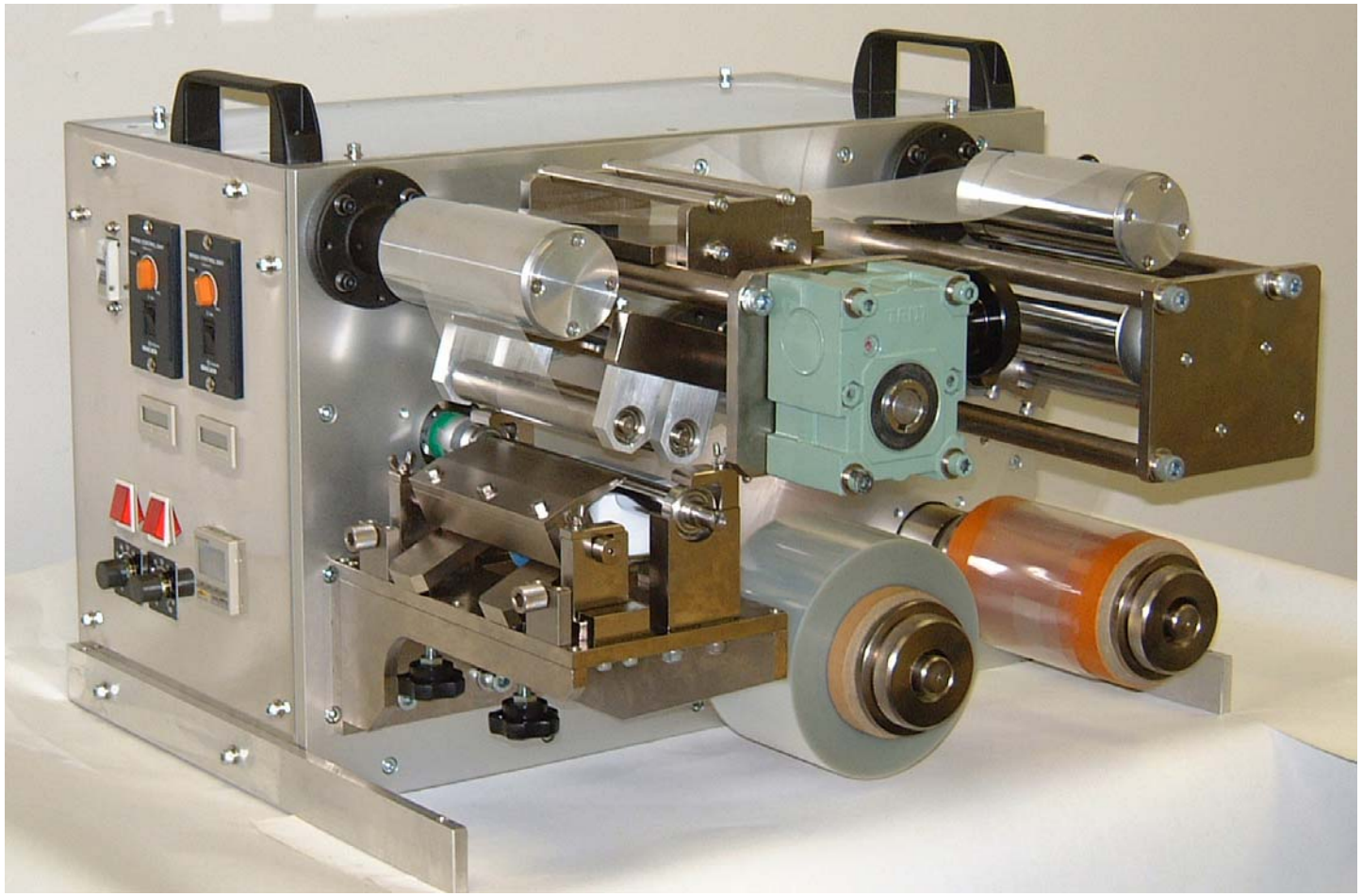
Laboratory Continuous Coater

Continuous Dryer Type KTF

This dryer with attached coating head at its entrance is the smallest continuous coating range. The dryer has a nozzle box with an upper and lower section. In front of the dryer entrance following elements can be placed: unwinding device, coating head, laminating device and IR-predryer. At the dryer exit another laminating device can be added.
For continuous processes with different treating temperatures several dryers can be used.

material width	300 or 450 mm
coated width	250 or 400 mm
running speed	0.1–2 m/min
material cont. dryer	0.9 m
temperature	up to 250°C
heating capacity	approx. 9 kW
space requirements	approx. 2.5 x 1 m

Bench-top Continuous Coater



Yasui-Seiki

Pilot Coaters

- **New class of modular coaters**
- **Semi-custom**
  - Can select standard modules to meet your needs
  - Coating, dryers, control systems
- **Typical configuration**
  - Width up to 18 inches
  - Line speeds to 130 f.p,m
  - Modular zoned dryers
  - Single position unwind rewind
  - Complete control systems
  - compact

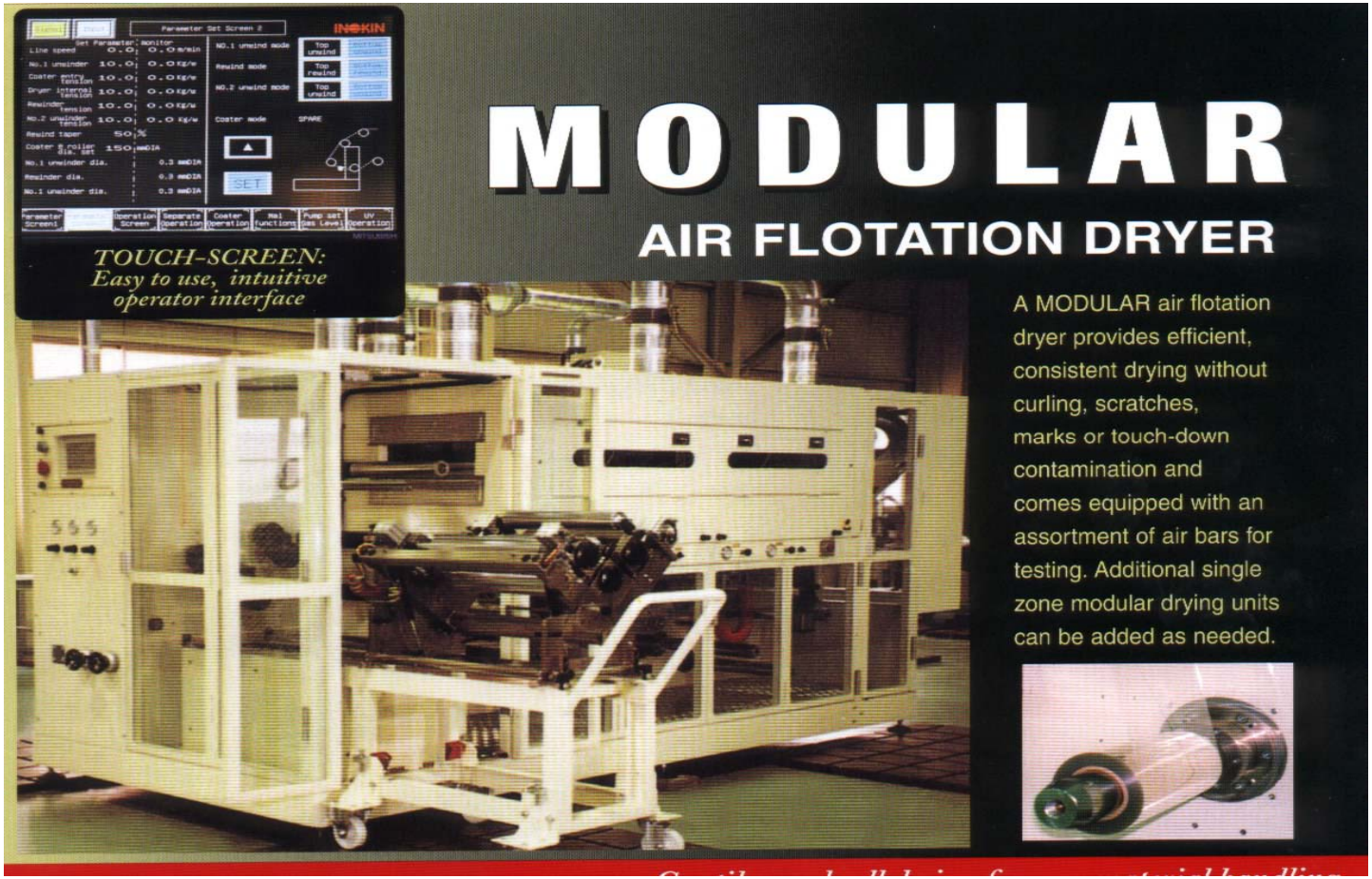
Pilot Coater Modules

- **Coating methods**
  - Die, reverse roll, gravure, Microgravure™, Kiss Dip
- **Dryer**
  - Flotation, IR
  - Add modules as needed
- **Laminating**
- **U.V.**
- **Unwind**
  - Continuous if interested,
- **Computer control systems**

Modular Coater Advantages

- **Good for**
  - R&D,
  - Development,
  - Production
- **Commercial quality**
- **Reproducible and versatile**
- **Can be used to manufacture small volumes**

Inokin


INOKIN
MODULAR
AIR FLOTATION DRYER
TOUCH-SCREEN:
Easy to use, intuitive
operator interface
A MODULAR air flotation dryer provides efficient, consistent drying without curling, scratches, marks or touch-down contamination and comes equipped with an assortment of air bars for testing. Additional single zone modular drying units can be added as needed.

Future Advances

- **Use new technologies will expand**
- **More versatile coaters**
  - Multiple coating methods.
  - Impingement UV IR dryers
  - Wide range of supports thickness & type
  - Coat wide range of coverage's
  - Increase in width coated
- **Increase in multilayer structures**
- **Hot melt coaters increased usage**
- **Reduced dependence on oil**
  - More focus on energy use efficiency
  - Increased use of natural product supports

Facilities Comparison Past & Present

late 20th century

- **Manufacturing coater**
  - Low speed, narrow
  - Long dryers
    - **festoon, ss imping**
  - Applicator
    - **Single layer**
    - **Mayer rod, roll, air knife, blade**
    - **One technique per coater**
  - Thick coatings
- **Energy consumption not concern**

21th century

- **Manufacturing coater**
  - High speed, wide
  - compact high rate dryers
    - **Floaters, IR, hybrids**
  - Versatile
  - Multiple Applicators
    - **Multilayer**
    - **Slot die, reverse roll, gravure**
  - Wide range thickness & substrates
  - Online measurements & control
  - Energy efficient
  - Intelligent control systems
  - Emissions control
  -

Facilities Comparison Past & Present

late 20th century

- **Laboratory**
  - Sheet coatings
  - Mayer rod
  - Dies
  - Oven dry or bench top dry

21th century

- **Laboratory**
  - Hand coating minimal
  - New technology
    - **Automated sheet coater**
    - **bench top continuous**
    - **Modular pilot coaters**
    - **Multilayer laboratory capability**