Non-Nuclear Alternatives for On-Line Coating Thickness and Moisture Measurement

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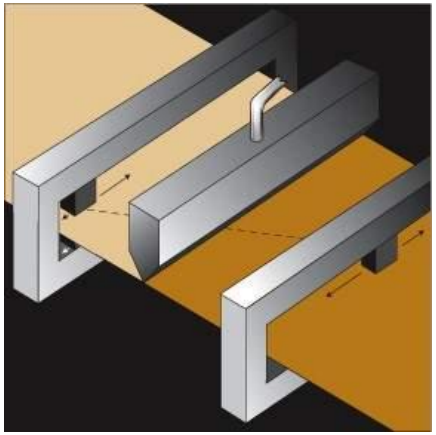
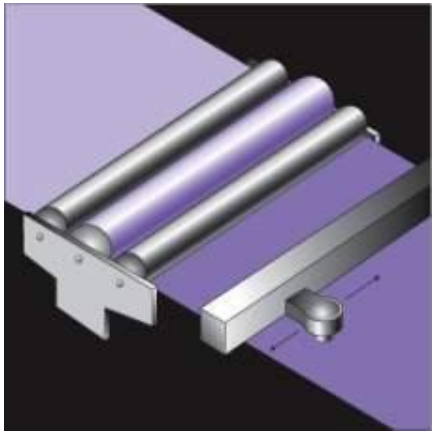
For Organic Coating Measurement, New Non-Nuclear Sensors Offer:

- Greater Accuracy with Better Resolution
- In Some Cases, Reduced Hardware Requirements
- No or Minimized Government Regulatory Requirements
- No Disposal Costs
- Self-maintenance
- ***Lower Lifetime Cost with Greater Lifetime Benefit***

2 Types of Common Non-Nuclear Gauges: Total Weight and Selective

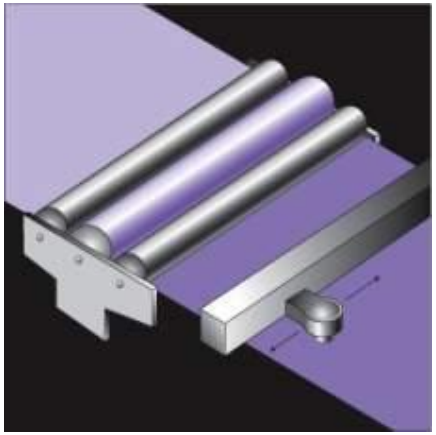
- Total Weight Gauges:
  - X-Ray Transmission and Backscatter
  - Measure total weight
  - Determining Coat weight requires differential measurement
    - Measure base stock, then measure total weight and subtract
    - Requires at least two sensors / scanners
- Direct Coat Weight Gauge:
  - Infrared gauge
  - Directly measures the coating
    - A single gauge / scanner does the job

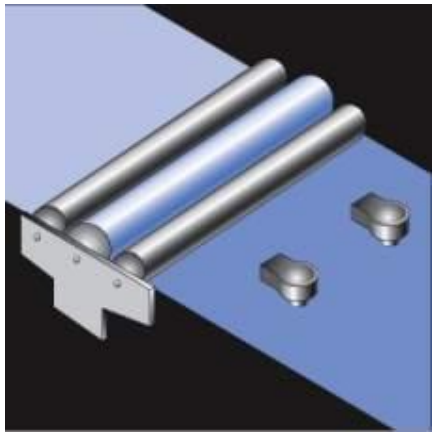




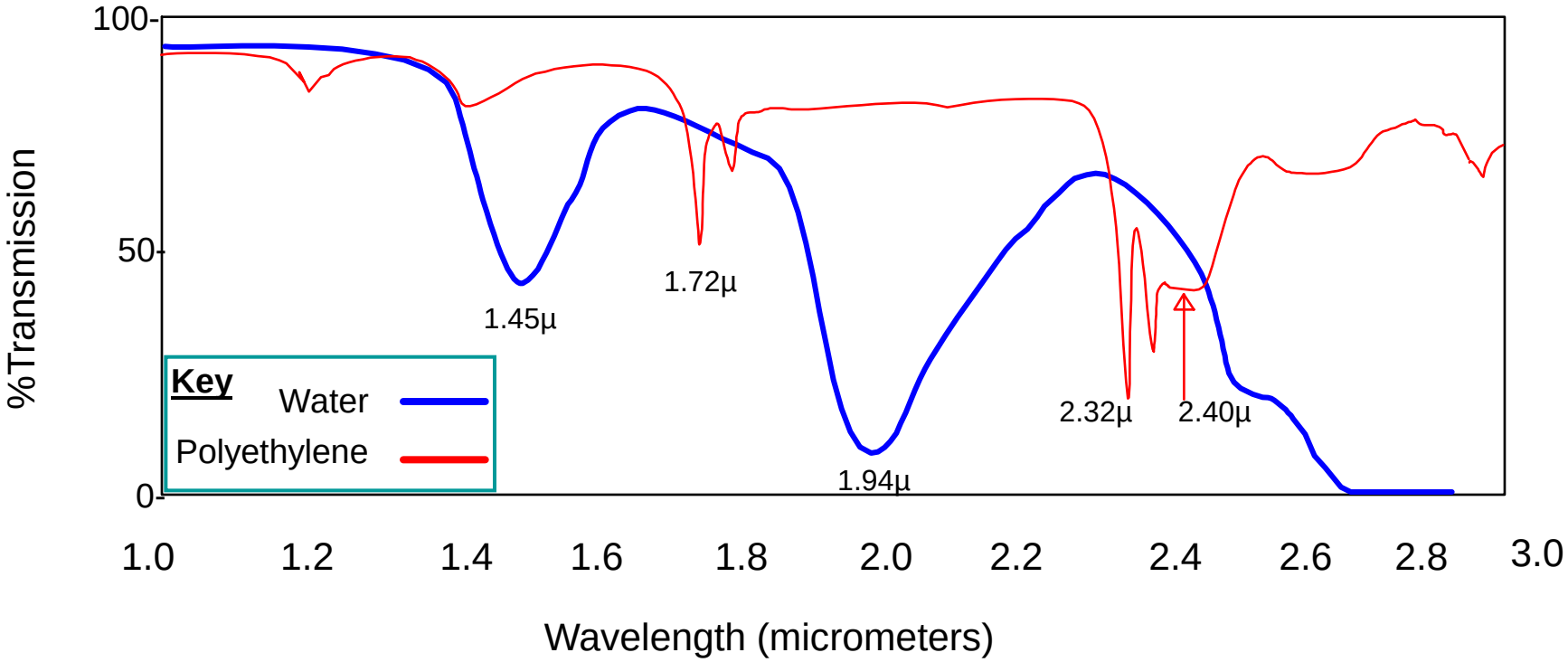
Let's Discuss Selective Infrared Measurement Approach First

- Selective approach requires only one gauge after the coating station
  - Less expensive
  - More accurate
- Scanning gauge
  - Common for Coating Measurement
- Single / Dual fixed gauge(s) (L/R)
  - Common for Moisture Measurement, Narrow / Slow Lines





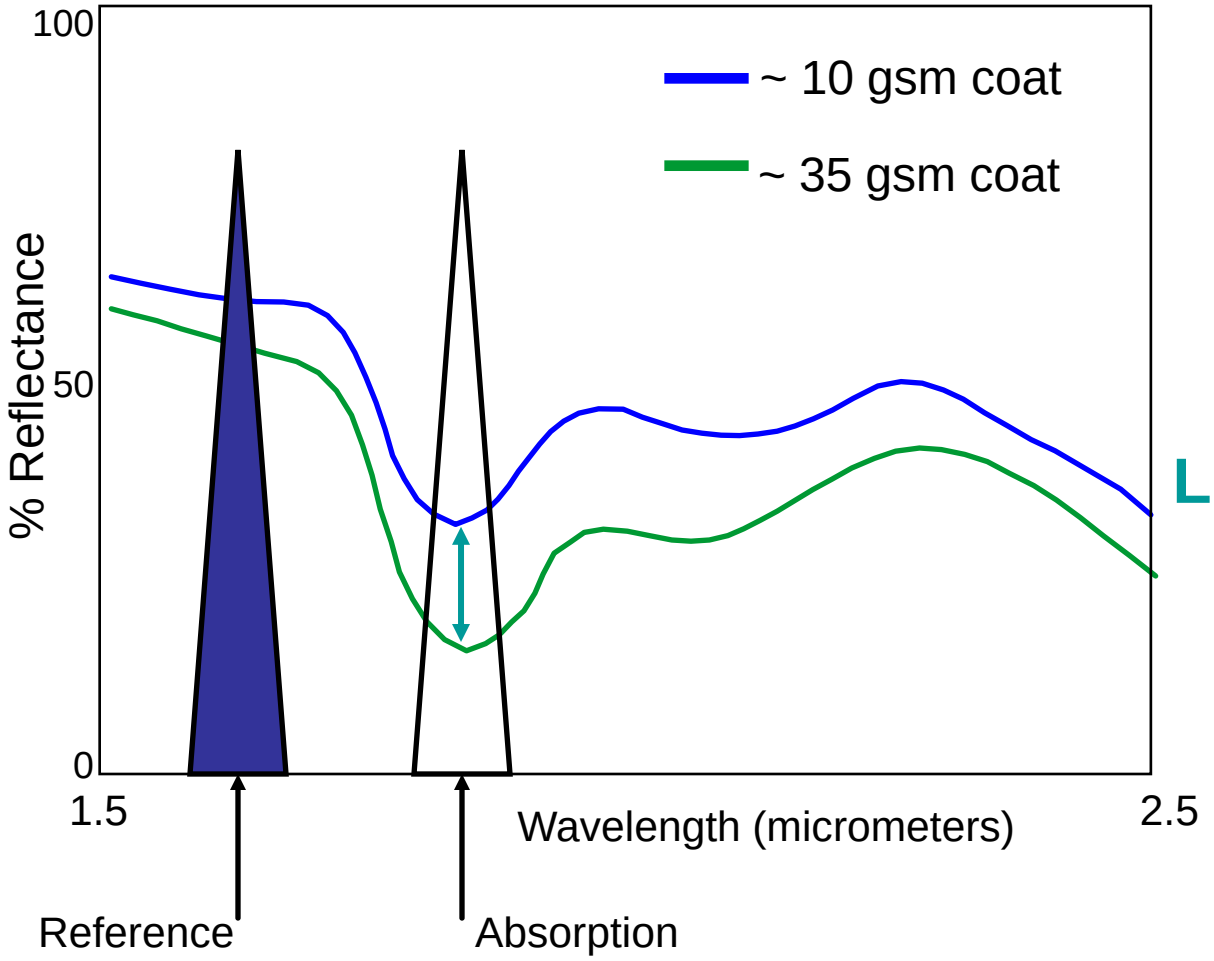
Infrared is a Selective Technique



Application example:

Thin water based coating on PE is trivial for IR

Basic Two-Wavelength Measurement

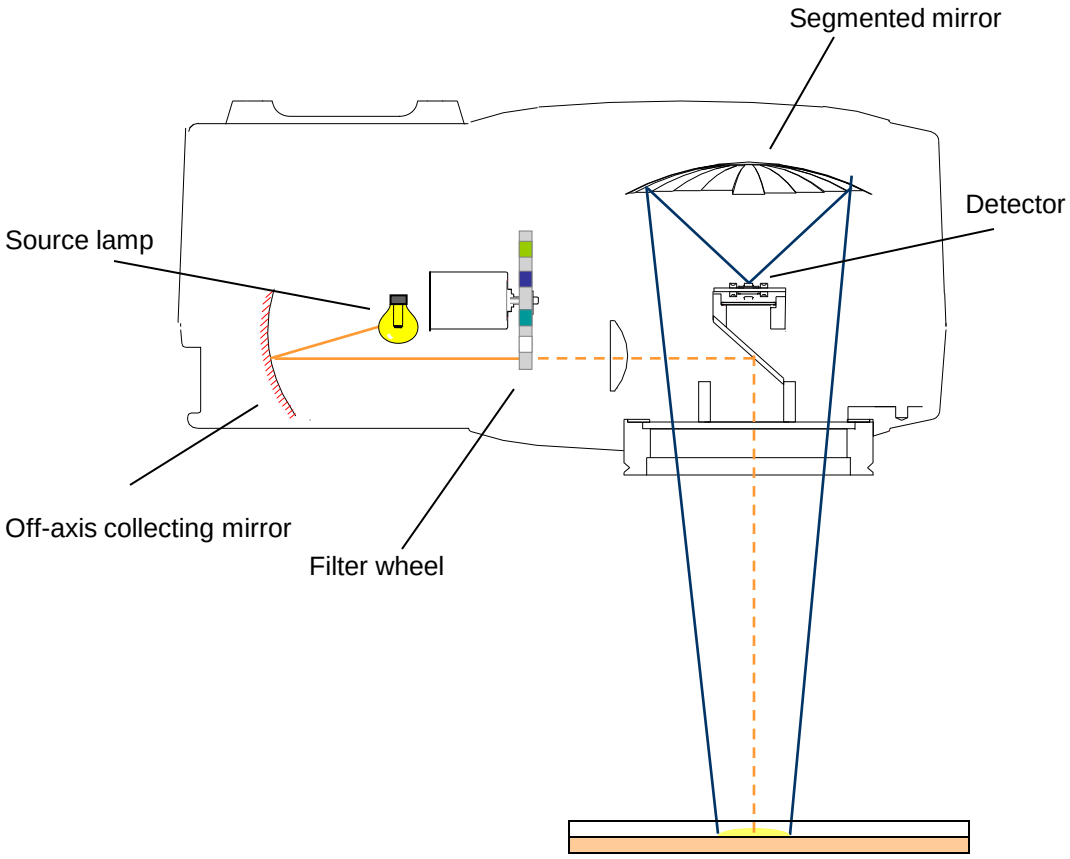


"Absorption"
absorbed by coating

"Reference" NOT
absorbed by coating

$$\text{Log}\left\{\frac{\text{Sig}\lambda_{ref}}{\text{Sig}\lambda_{abs}}\right\} \propto \text{GSM}$$

Infrared “Filter Wheel” Gauge Optical Schematic

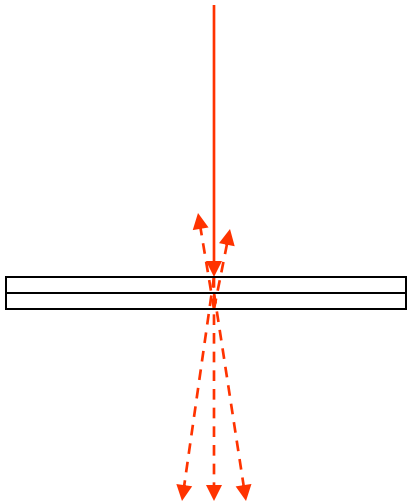


Typical IR Backscatter Gauge on Coating Application

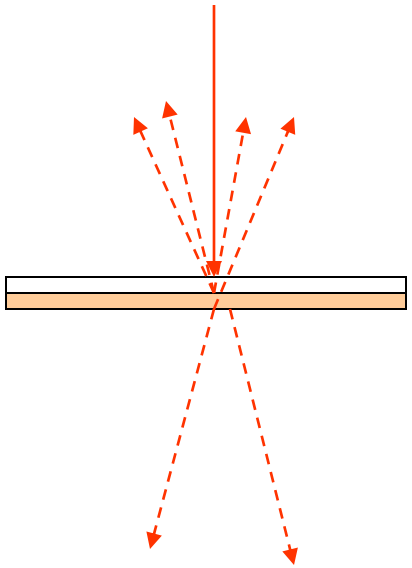
- Ranges / Accuracies:
- Moisture
  - Range: 0 – 90% moisture
  - Accuracy: 0.1%
- Coating Weight
  - Range: 0 – 1000 gsm
  - Accuracy: 0.1 gsm

- Note that these values are product / substrate dependent

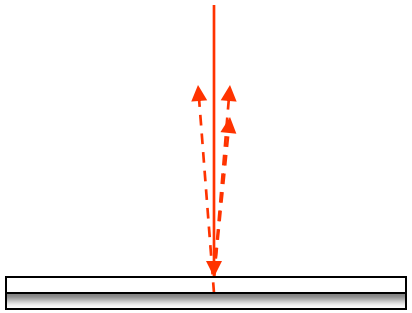
Three types of IR energy behavior when interacting with various substrate types



Transmission -
Clear Coatings
on Clear Films



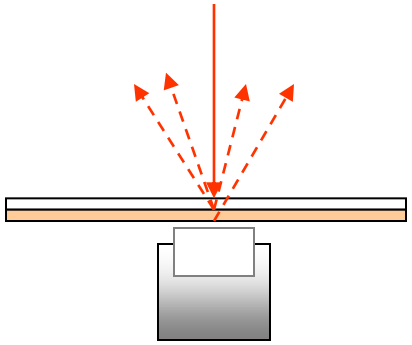
Diffusion -
Clear Coatings on
Pigmented Films, Paper



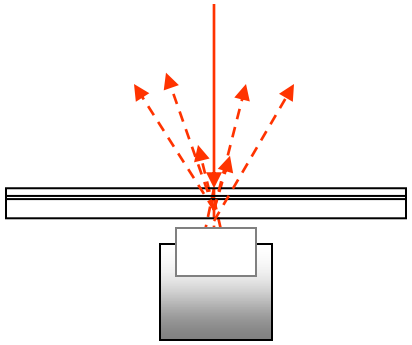
Specular Reflection -
Clear Coatings on Metals,
Foils, Metallized Films

The Way Light interacts with the web has a direct influence on gauge design / optics

With IR Backscatter Running Multiple Substrate Types, Use Diffuse Reflector



- With Diffuse Substrate, Reflector is Passive, Coating Measurement is Made



- With Clear Substrate, Reflector Sends Diffused IR Light back to Gauge Receiver, Enabling Measurement of Coating AND Film

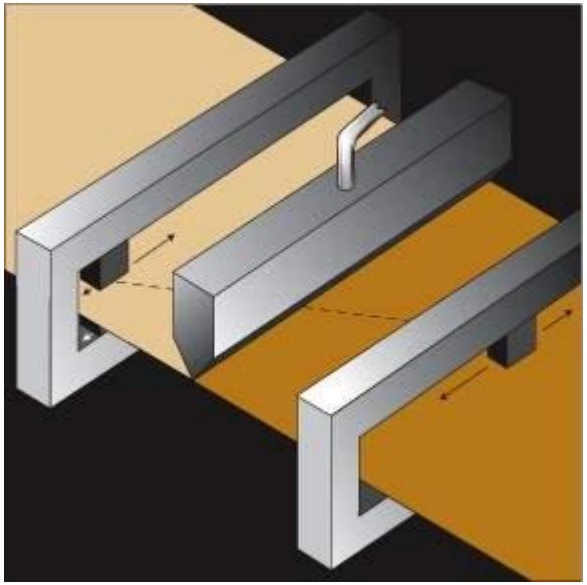
When Running Clear, Diffuse, and Metallic Substrates, Use SR Gauge with Reflector

For Some Applications, Direct Selective Measurements are not Possible

- IR Selective technique does have limitations:
  - IR cannot measure opaque materials
  - Materials might be similar in composition
    - No discernable absorption band that measures just coating
- In these situations, a differential measurement may be the only solution

Differential Measurement Technique Using Multiple Total Weight Gauges

- First sensor reads substrate weight
- Second sensor reads total weight
- Gauge readings are “subtracted” to obtain coat weight



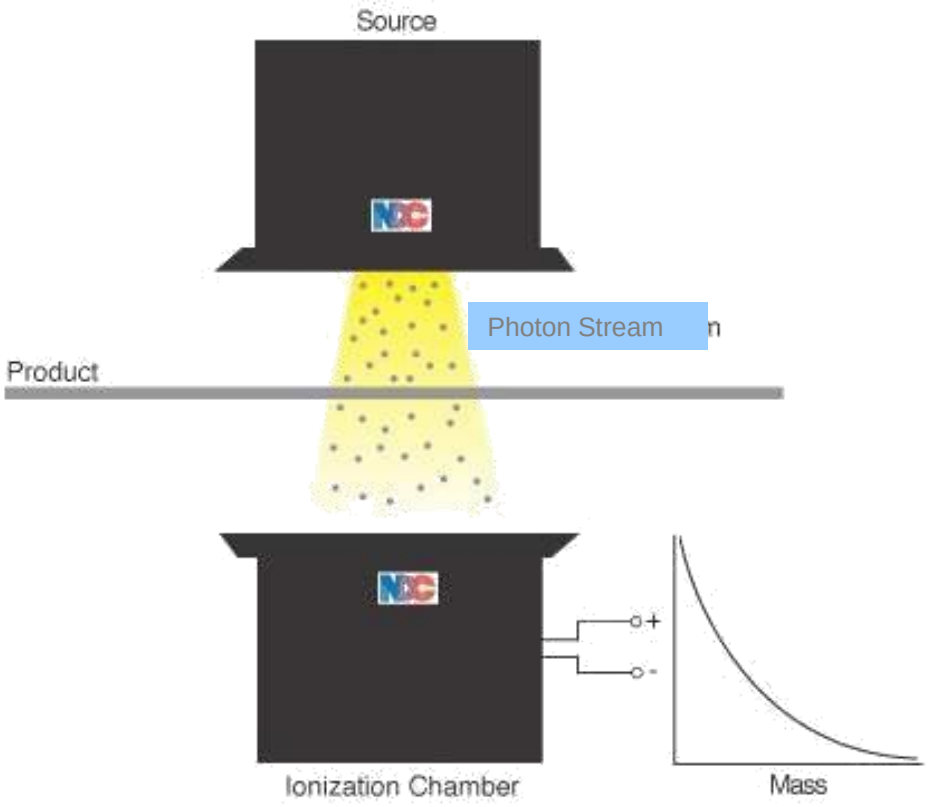
X-Ray Sensor Types

- Transmission
  - High Resolution
    - Good Streak and Edge Detection
  - Excellent Repeatability
  - Composition Sensitivity can be problematic

- Backscatter
  - Less expensive
    - Single-sided Scanner
  - Less Composition Sensitive
  - Less Repeatable
  - Lower Resolution

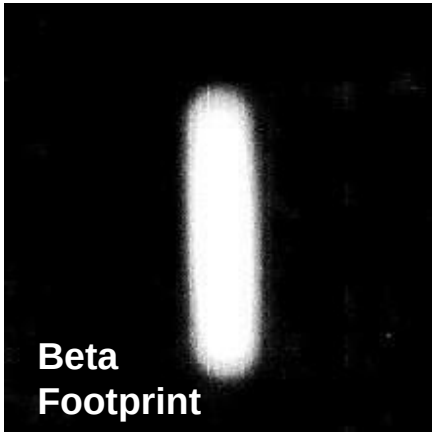
X-Ray Transmission

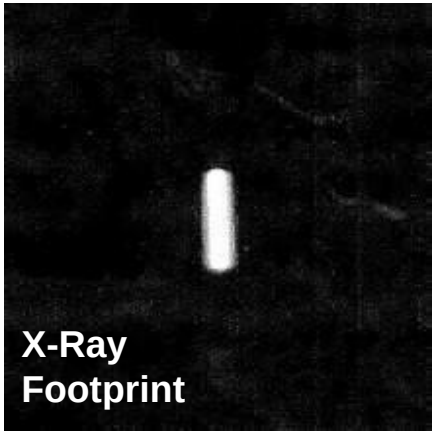
- Dual-sided sensor
- Generates photon stream through X-Ray tube, digital power supply
- Measurement range
  - Up to 10,000 gsm
- Some sensitivity to composition, presence of mineral / metal additives
- Total Weight Gauge
- Typical Repeatability: 0.1%



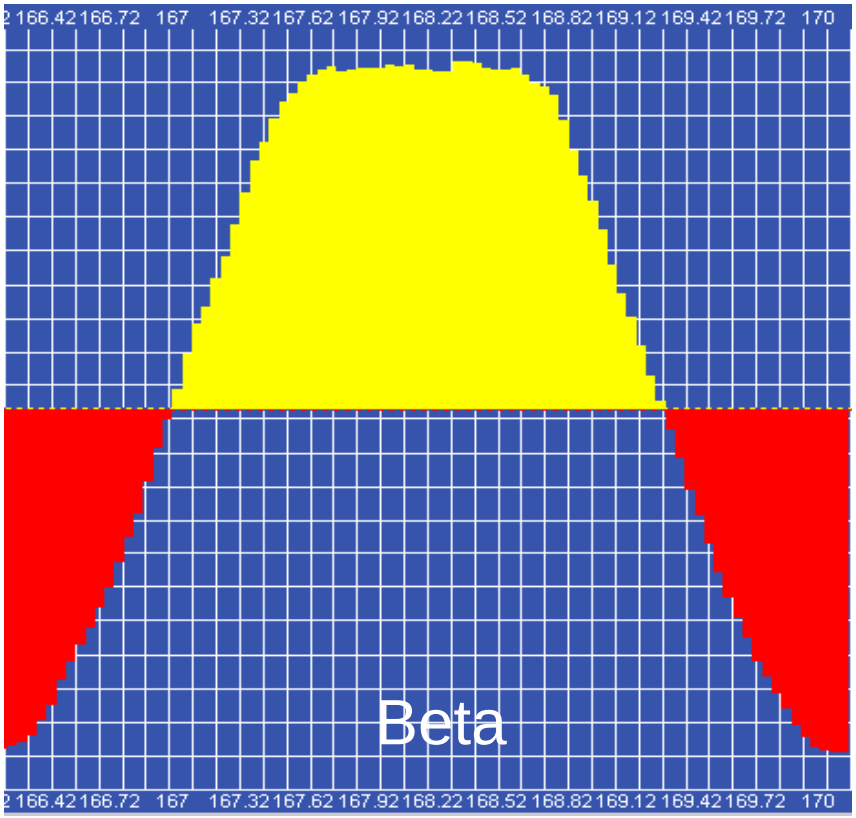
XRT Offers Several Advantages over Nucleonic Gauges

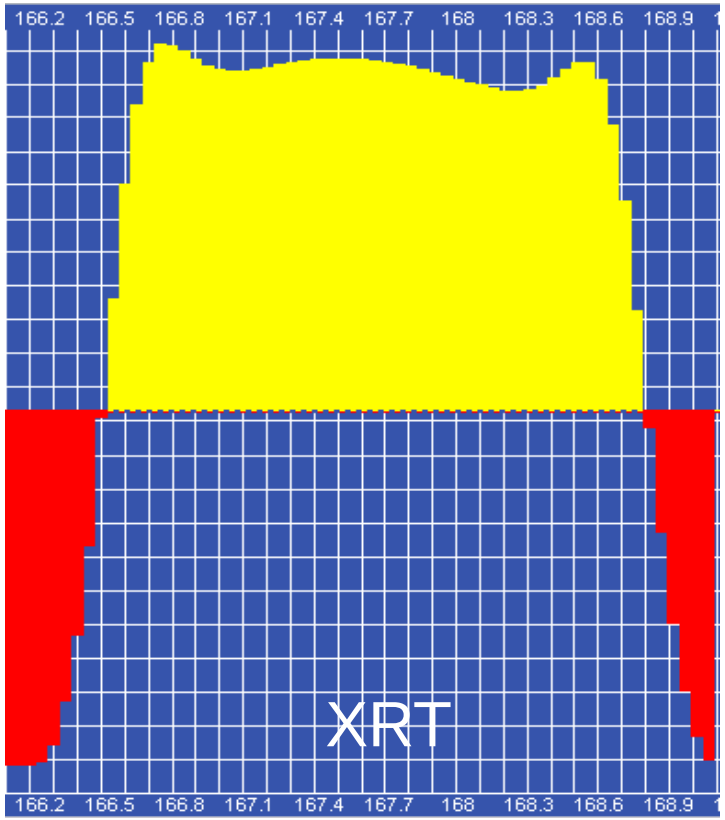
- Excellent Streak Resolution
- Higher Precision, Lower Noise
- Reduced Web Flutter Sensitivity
- Constant Output Over Time
- In Coating Applications, Gauge Readouts Can Be Easily Matched
  - Important for Improved True Net Coat
- With Power removed, no radiation





XRT Sensor Profile Detail Vs Beta Gauge

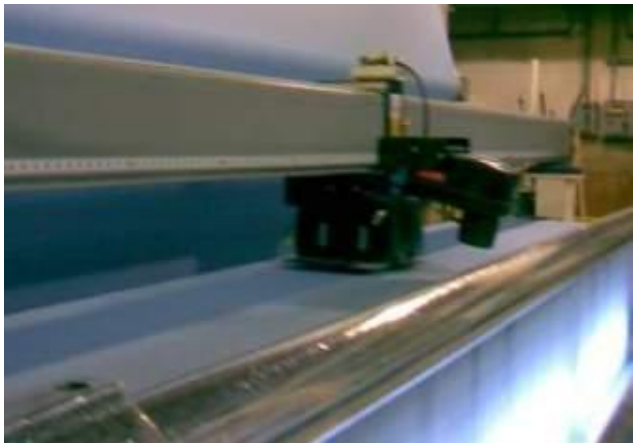




Magnification of ½” strip coating between ½” uncoated areas

X-Ray Backscatter (XRB)

- X-Ray Tube generates photons; Ion Chamber measures reflected energy
- Total mass measurement gauge (wt/area)
- Single-sided Measurement
  - Less Expensive
- Range 10 – 25000 gsm
- Lower sensitivity to composition
- Typical Repeatability: 0.3%



One Problem with Differential Approach: Accuracy is Function of **TOTAL** Mass

- Differential Technique is viable when coat weight is a significant percentage of base weight
- Otherwise, cumulative errors render gauging approach useless
- Example, using gauges with 0.25% accuracy:

$$Err_{Coat} = \sqrt{Err_{Base}^{\ 2} + Err_{Gross}^{\ 2}}$$

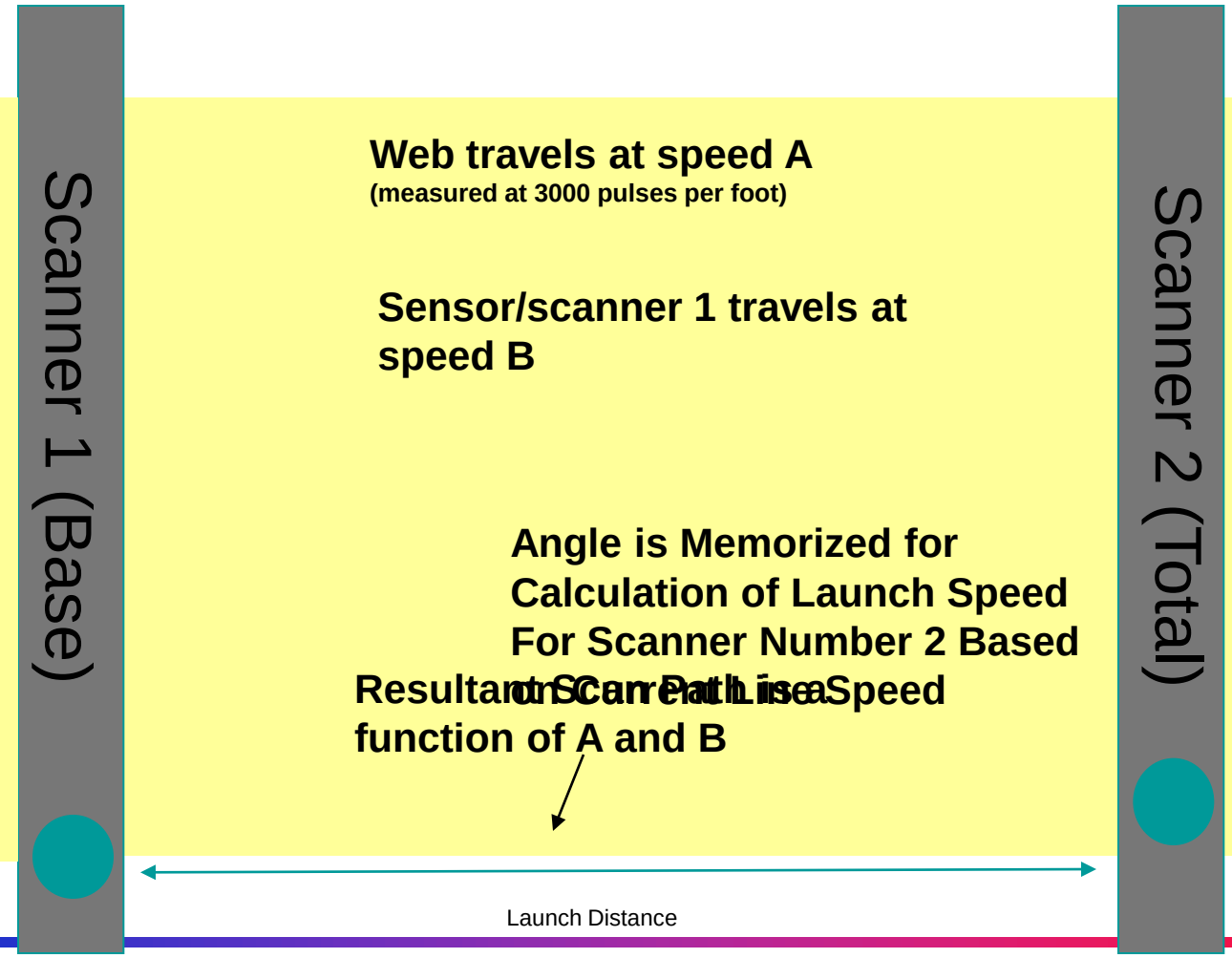
- Substrate = 100 gsm
- Coating = 3 gsm
- Coat error = SQRT $((100*.0025)^2+(103*.0025)^2)$
- Coat weight error = 0.36 gsm
- Coat weight error = **12%**

Rule of Thumb: Coating Must be AT LEAST 10% of Substrate Weight

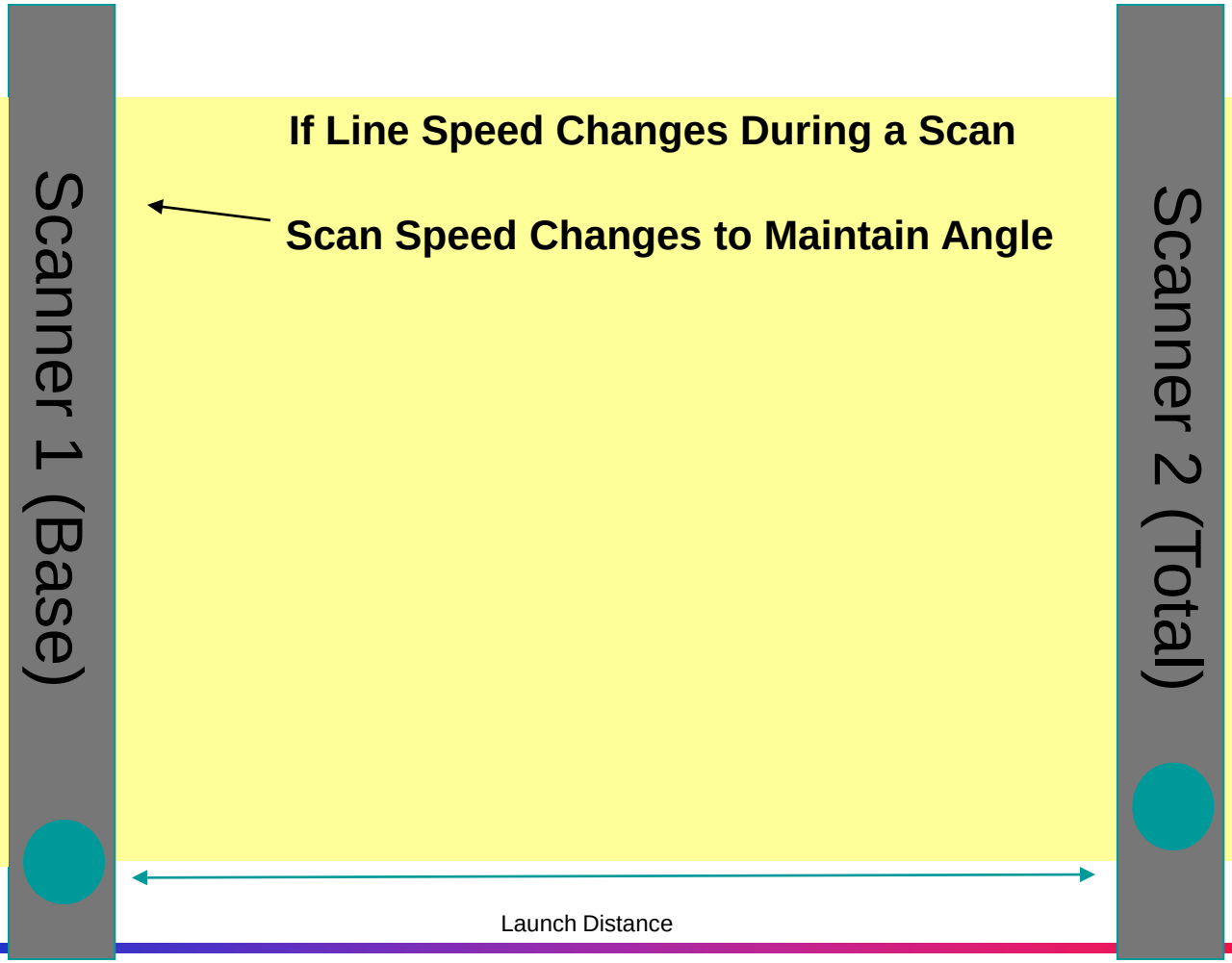
Other Challenges with Differential Technique and Typical Solutions

- Substrate has basis weight variation
  - Provide accurate “Same Spot” method so that both sensors see same area of base material when making measurement
- Compositional effect
  - Use “True Net Coat” algorithm
    - Works well with XRB
    - Needs to be carefully applied with XRT

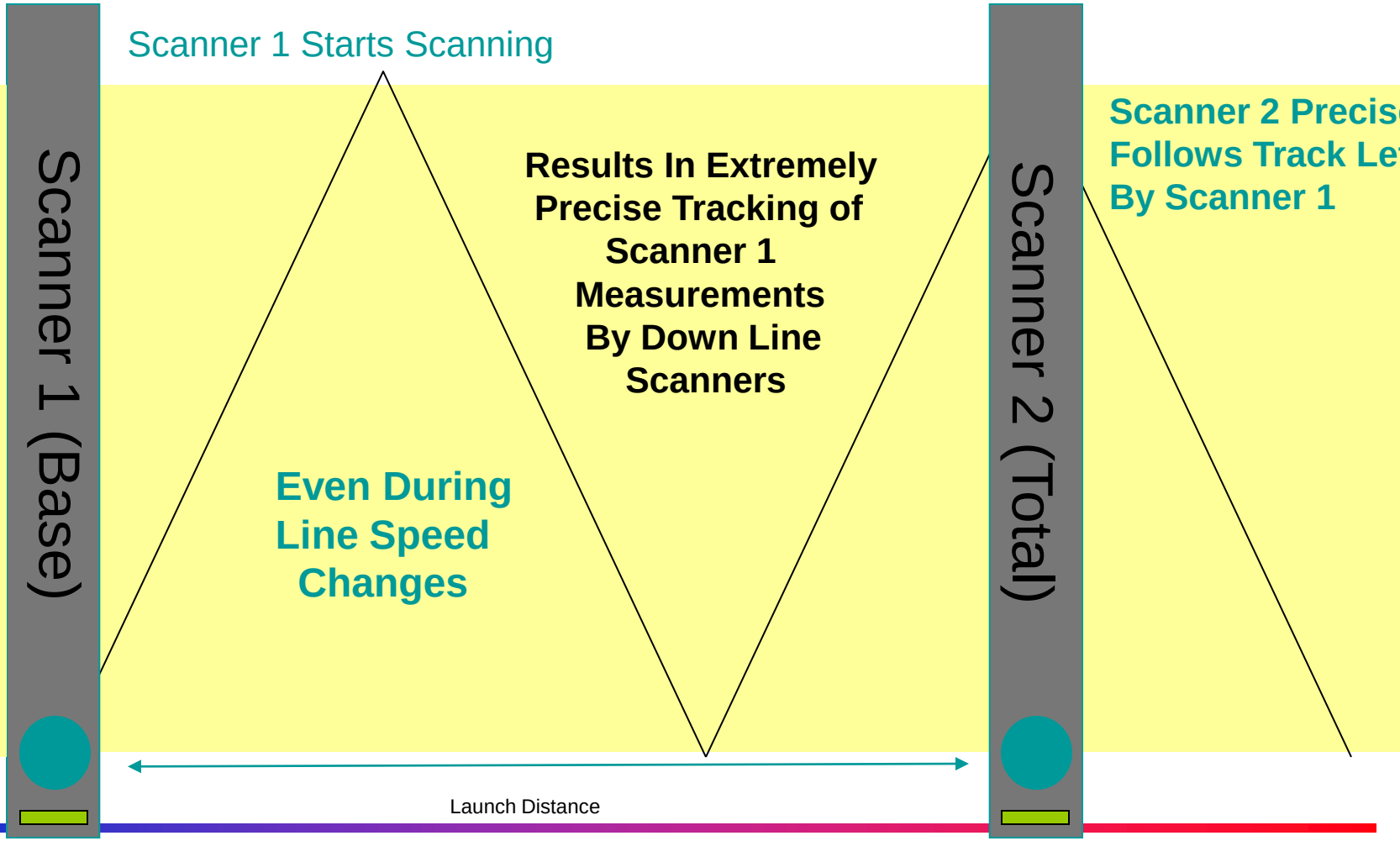
Same Spot Measurement



Same Spot Measurement

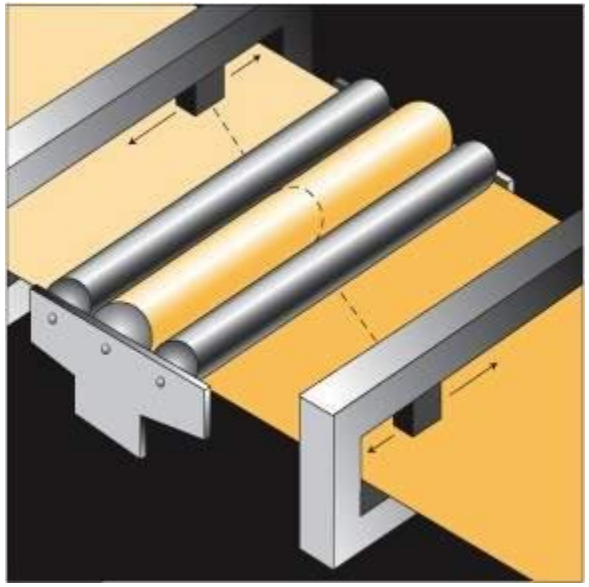


The Result of Same Spot Measurement



Keys to Good Same Spot Measurement

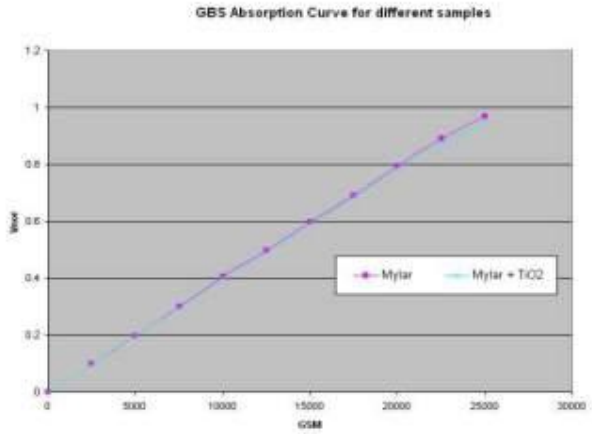
- Launch of scanners based on distance, not time
  - Line speed can change
  - Use high resolution digital pulse encoder to control launch
- Scan speeds must be slaved to line speed
  - To maintain constant vector angle



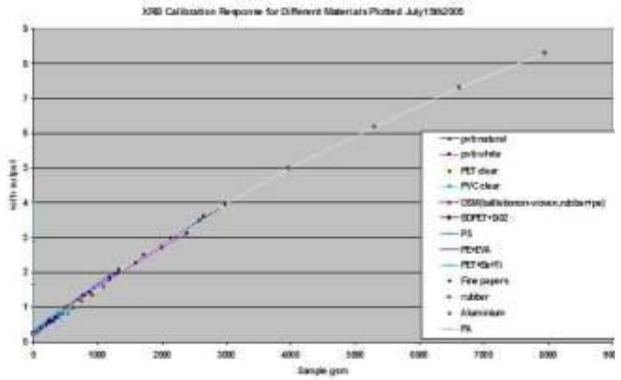
Problem 2: Composition Sensitivity

- With some types of gauges, composition of the material can change the reading
  - A function of Atomic weight / atomic number ratio
- This effect can compound coat measurement errors as the substrate may have a different composition effect than does the coating
  - e.g.: Clear Organic Coating on Foil Substrate
  - e.g.: Pigmented Coating on Clear Substrate
- In these cases, the system must incorporate a “True Net Coat” algorithm

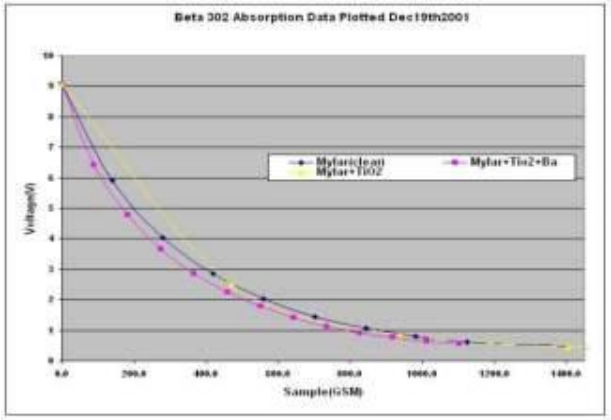
Effect of Fillers on Various Sensor Types



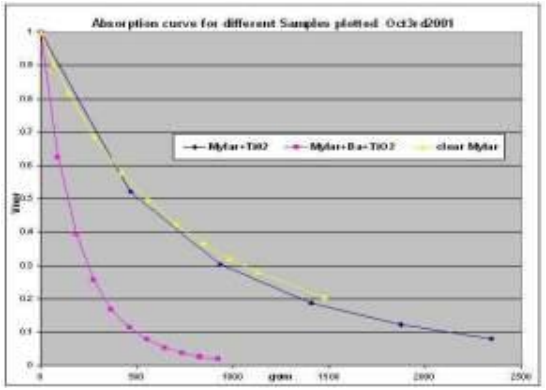
Gamma Backscatter



X-Ray Backscatter



Beta Transmission



X-Ray Transmission

Final Comments: Non-Nuclear Gauge Selection

- Accuracy with Differential Systems
  - Function of RMS of errors gauges employed, based on the TOTAL weight being measured
  - Accuracy only obtained as long as substrate variability and composition effects are managed
    - Same Spot / True Net Coat
- If Selective Infrared can be used, a better choice
  - Single scanner / sensor = Lower cost
  - Greater Accuracy
  - Ability to measure multiple constituents
    - Coating
    - Moisture
    - Polymeric Substrates
  - No Ionizing Radiation

Questions?