FACTS, Inc.
PROCESS CONTROL SYSTEMS

Total Solutions for the Rubber & Plastics Industries

Measurement System Developments

For

The Building & Industrial Mat Committee

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By:
Tim Fisher, Owner
***FACTS*, Inc.**
2737 Front St.
Cuyahoga Falls, OH 44221
Phone: 330-928-2332
Email: TFisher@facts-inc.com
Website: www.FACTS-Inc.com

After a brief description of the standard scanning measurement system architecture, and description of the historical measurement technology, this paper will present several new measurement technologies that are applicable to The Building and Industrial Mat Industries. It will also contrast these new technologies with the traditional measurement technology and present a list of pros and cons for each technology.

There are a wide range of measurement and sensor technologies available. Each has unique capabilities and limitations, so the selection of the best sensor technology must evaluate the specific application requirements against the sensor being considered. Figure 1 provides a list of some of the various technologies applied to the web process industry.

Figure 1

Most scanning measurement and control systems have a basic architecture similar to that shown in Figure 2.

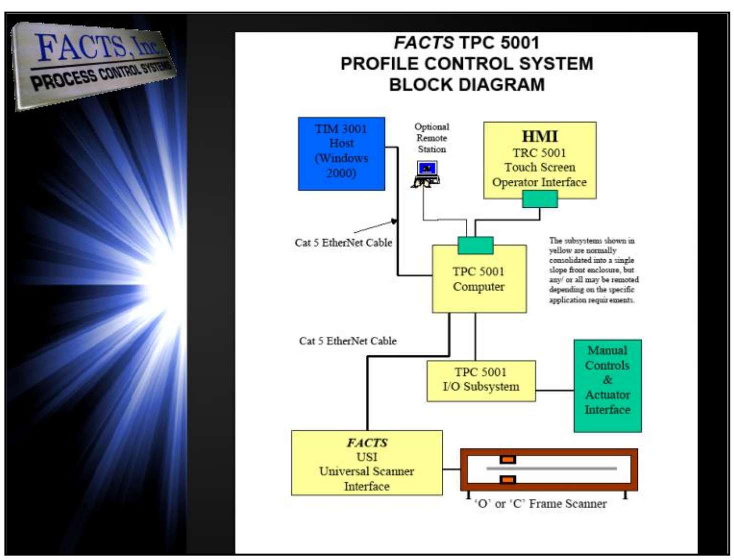


Figure 2

The ***FACTS*** system architecture is somewhat unique in that it is designed to accept almost any sensor from any sensor supplier and can be used for new systems or as an upgrade for existing measurement systems. This architecture supports multiple sensor technologies with multiple sensors on each scanning frame along with multiple scanning frames in a single total measurement system.

Typical operator screens for a scanning measurement system are provided in Figures 3 & 4.

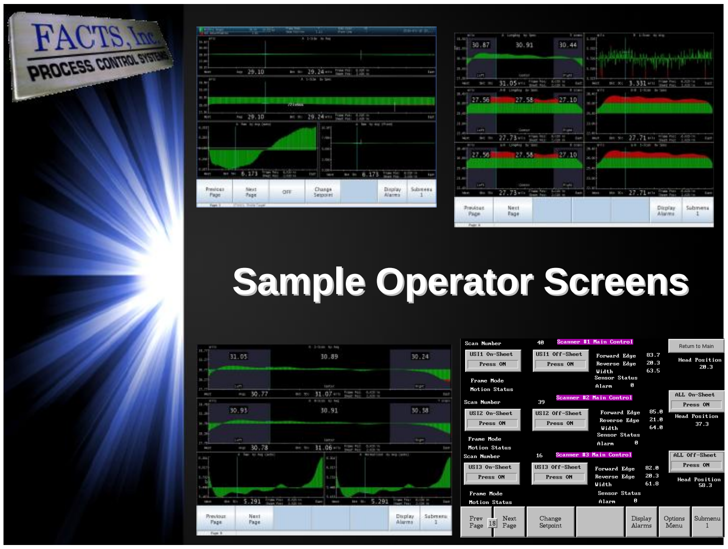


Figure 3

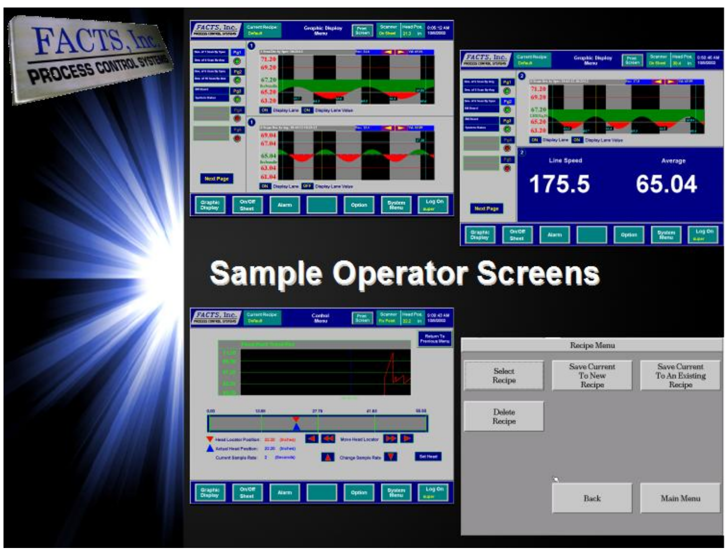
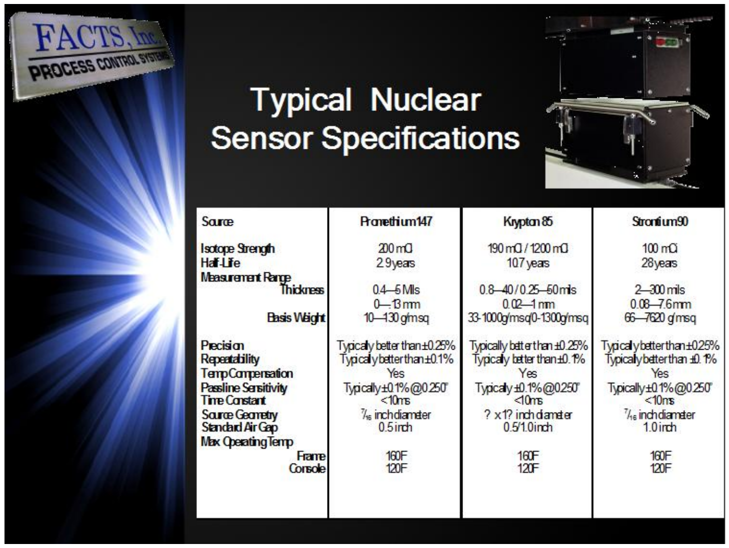


Figure 4

The historical measurement technology has been nuclear transmission or backscatter based. These systems measure the absorption (transmission sensor) or scatter (backscatter sensor) of nuclear particles from a nuclear source. This is a very non-linear measurement and an exponential curve is utilized to determine the web basis weight or thickness. A set of known samples is used to generate the unique curve for each specific sensor.

Typical nuclear sensor specifications are provided in Figure 5 and a scanning gauge frame shown in Figure 6.



Source	Promethium 147	Krypton 85	Strontium 90
Isotope Strength	200 mCi	190 mCi / 1200 mCi	100 mCi
Half-Life	2.9 years	10.7 years	28 years
Measurement Range			
Thickness	0.4—5 Mils 0—.13 mm	0.8—40 / 0.25—50 mils 0.02—1 mm	2—300 mils 0.08—7.6 mm
Basis Weight	10—130 g/msq	33-1000g/msq/0-1300g/msq	66—7620 g/msq
Precision	Typically better than ±0.25%	Typically better than ±0.25%	Typically better than ±0.25%
Repeatability	Typically better than ±0.1%	Typically better than ±0.1%	Typically better than ±0.1%
Temp Compensation	Yes	Yes	Yes
Passline Sensitivity	Typically ±0.1% @0.250"	Typically ±0.1% @0.250"	Typically ±0.1% @0.250"
Time Constant	<10ms	<10ms	<10ms
Source Geometry	7/16 inch diameter	? x 1? inch diameter	7/16 inch diameter
Standard Air Gap	0.5 inch	0.5/1.0 inch	1.0 inch
Max Operating Temp			
Frame	160F	160F	160F
Console	120F	120F	120F

Figure 5

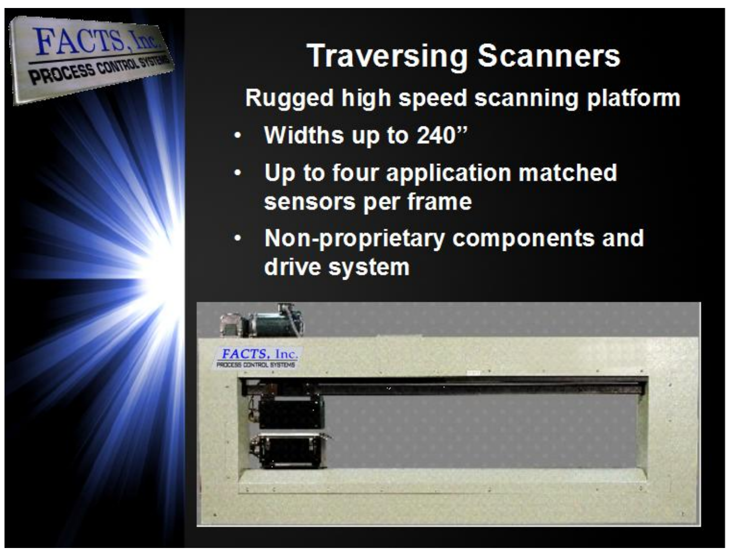


Figure 6

Figure 7 below presents a brief list of the Pros and Cons of measurement systems based on nuclear sensors.

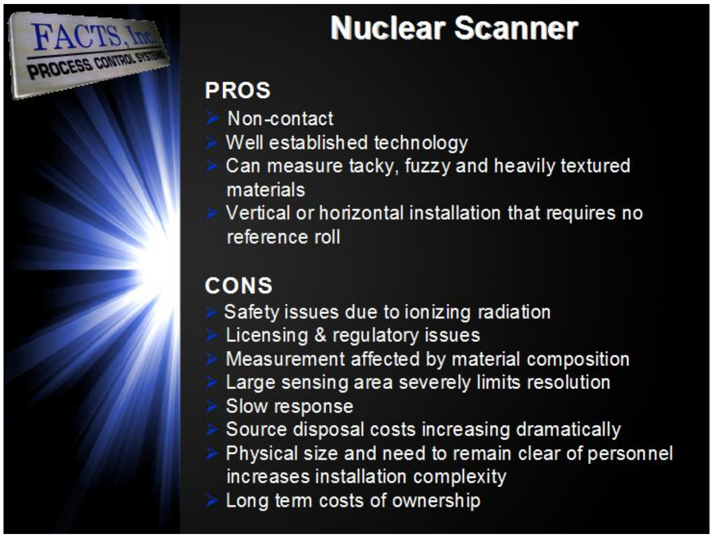


Figure 7

More recently several new technologies have become available that are appropriate for The Building Materials and Industrial Mat Industries. Each has unique capabilities and must be evaluated for the specific application.

The SME or Shadow Micrometer Eddy Current scanning measurement system provides a direct measurement of true thickness. This system has no ionizing radiation and is therefore safe to humans. It is non-contact, low cost, and simple to maintain.

Figure 8 shows the measurement principal of the SME sensor system.

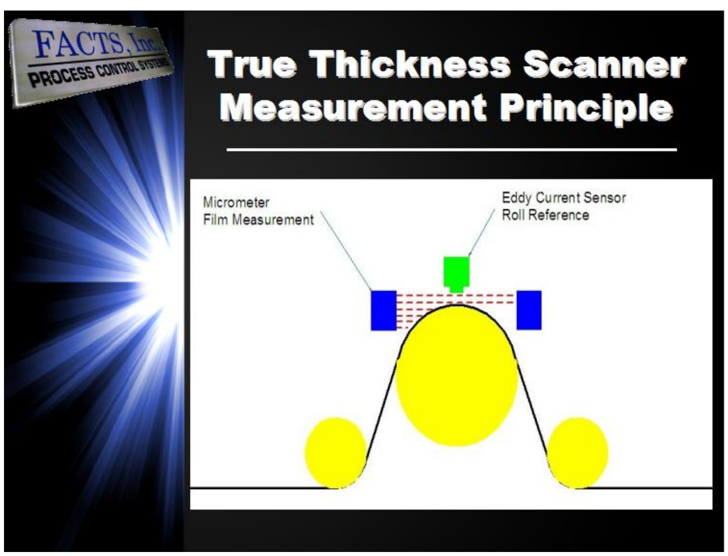


Figure 8

The SME gauge consists of 2 individual sensors sharing a common mount that is scanned across the web to be measured. The moving web is passed around a reference roll directly under the scanning sensor assembly. The Laser Micrometer looks across the stainless steel reference roll and accurately measures the change in the radius due to the thickness of the web being measured. Since no roll is perfectly round, bearings are not perfect, and the scanning mechanism is not perfectly straight, the Eddy current sensor compensates for these deficiencies by measuring the true relative position of the reference roll surface with respect to the Laser Micrometer. The difference between the roll surface (bottom of the web) and the top of the web as measured by the Laser Micrometer is the True Thickness of the web.

Figure 9 is a production SME gauge. Figure 10 is a close up of the sensor assembly that shows the Laser Micrometer and Eddy current sensor.

Figure 9

Figure 10

The SME gauge works well with transparent, textured, porous, sticky (on top side), or just about any non-conductive material.

Figure 11 below presents a brief list of the Pros and Cons of the SME gauge technology.

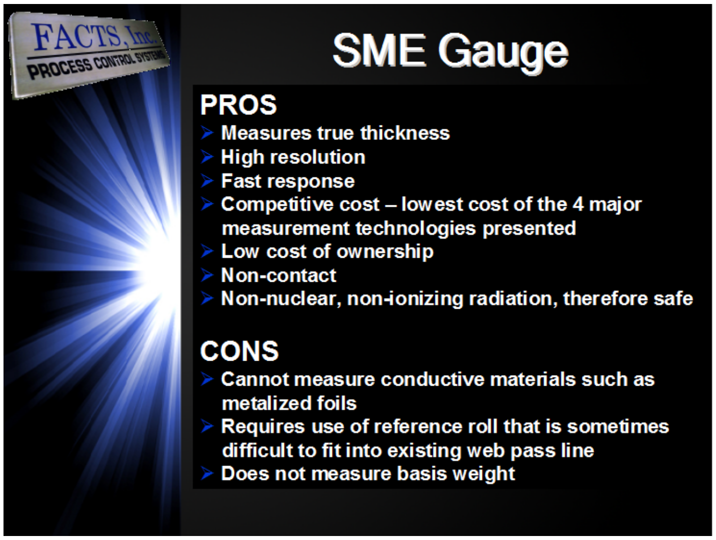


Figure 11

Figure 12 describes an application example involving the measurement of 2 different asphalt shingle samples. Figure 13 displays the results for a 160 lb shingle and Figure 14 is a scan of a 234 lb shingle. The addition of standard filtering would provide a very accurate measurement of overall thickness.

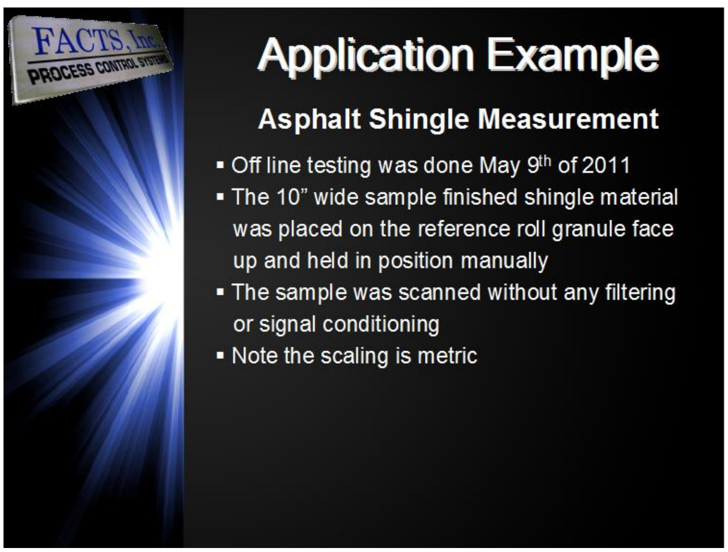


Figure 12

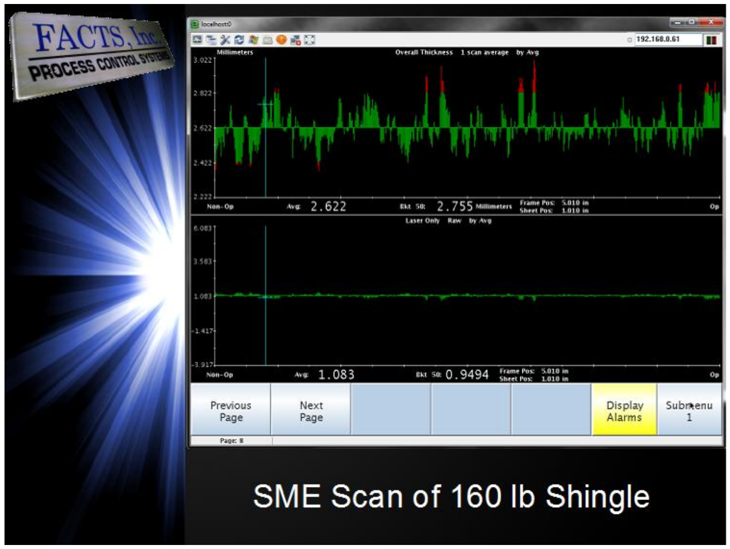


Figure 13

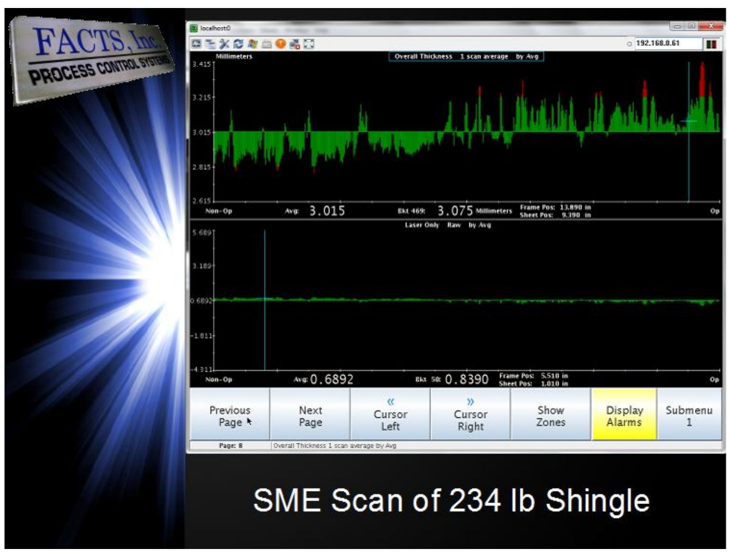


Figure 14

A closely related technology to the SME gauge is the LE or Laser Eddy gauge. This technology works the same way as the SME sensor but it replaces the Shadow Micrometer with a Laser Triangulation displacement sensor. This sensor directly measures the distance to the surface of the web. Its principal advantage is that less wrap of the web around the reference roll is required and less space on either side of the reference roll is needed.

The LE gauge can measure the height of ridges or other features on the web that are not measurable by the SME gauge. The LE gauge is less tolerant of porous, textured, and transparent materials.

Figure 15 describes the basic measurement principal of the LE gauge.

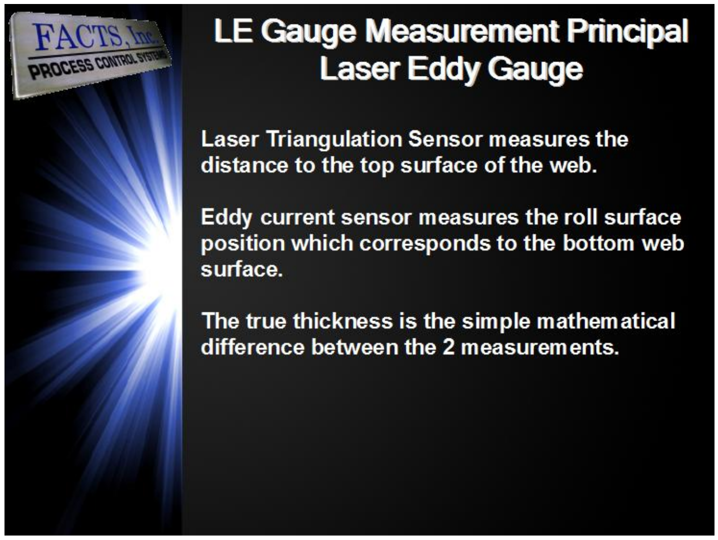


Figure 15

Figure 16 provides the basic pros and cons of the LE gauge.

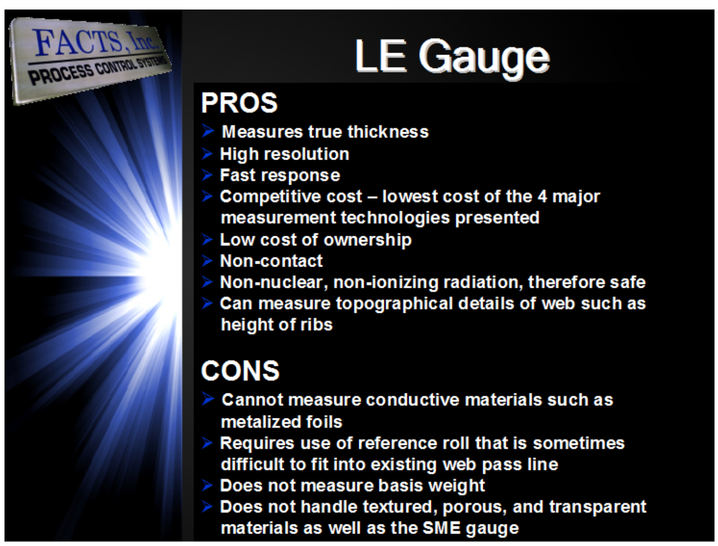


Figure 16

The most recently introduced sensor technology is the THz, or Terahertz, sensor. The THz sensor uses pulsed light to perform ToF, or Time of Flight, measurements and is very similar to radar in the way in which the signals are processed.

Figure 17 shows where the THz pulses fit into the overall electromagnetic spectrum.

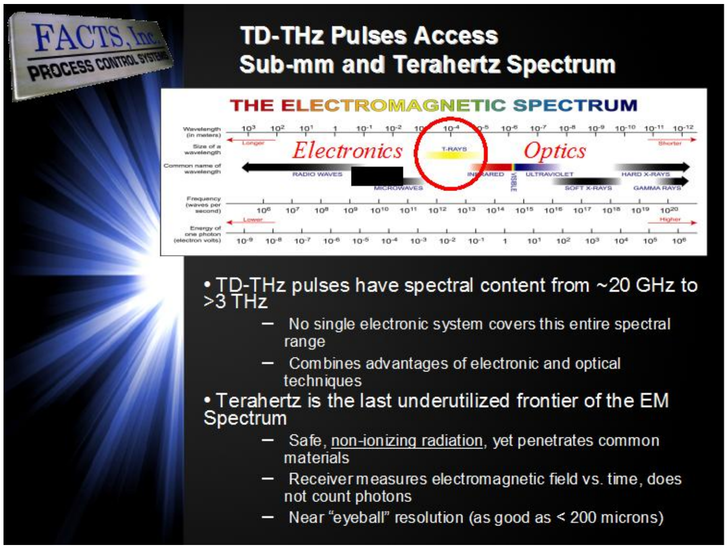


Figure 17

The THz sensor emits very short pulses of non-ionizing radiation, meaning it is safe to humans. Figure 18 provides a description of the THz pulses.

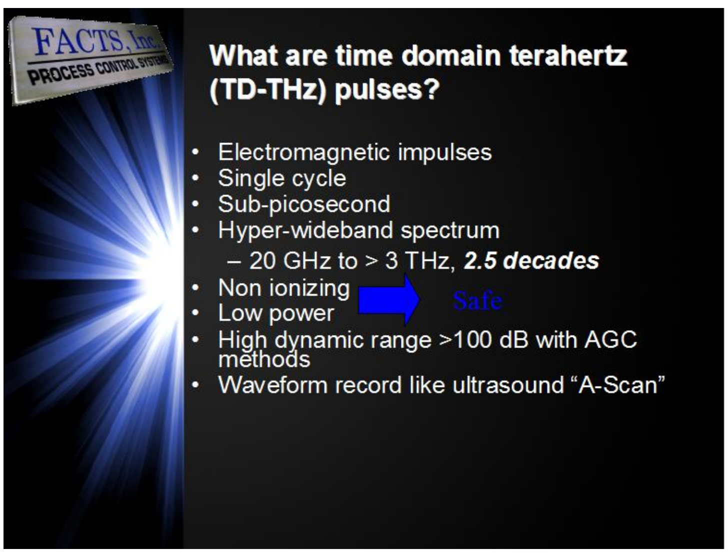


Figure 18

The thickness measurement is based on measuring the time difference between the partial reflection of the THz pulses from each surface of and within the web. If distinct layers are present, then measurement of the individual internal layers can be provided, as well as the total web thickness. Figures 19 & 20 graphically depict the Time of Flight measurement. The index of refraction for each material should be known or a sample of known dimensions must be tested in order to calibrate the instrument.

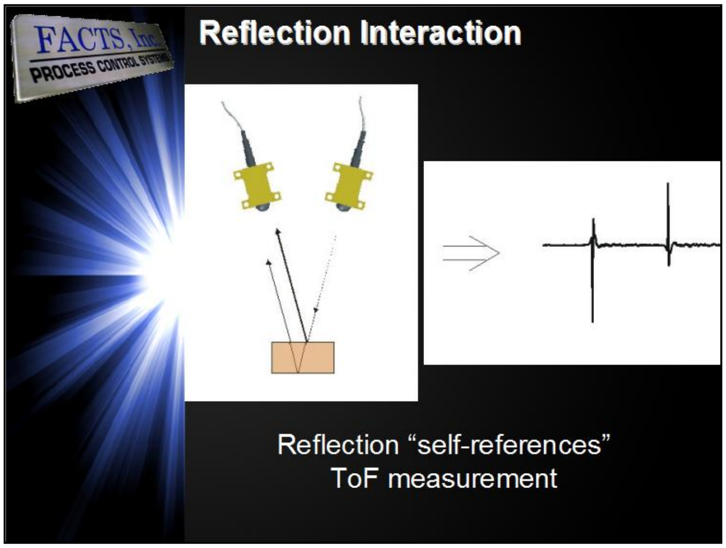


Figure 19

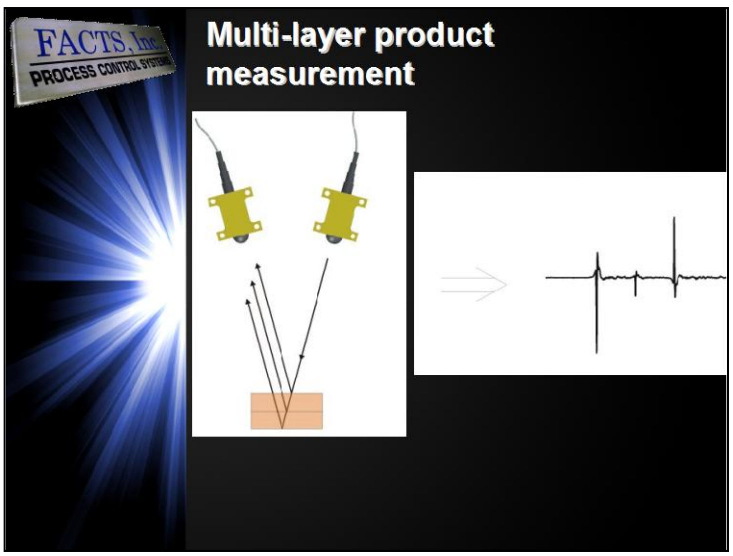


Figure 20

The THz technology can be used with a wide variety of materials. These materials need not be optically transparent but cannot be conductive. Figure 21 provides a partial list of the materials that can and cannot be measured utilizing the THz sensor.

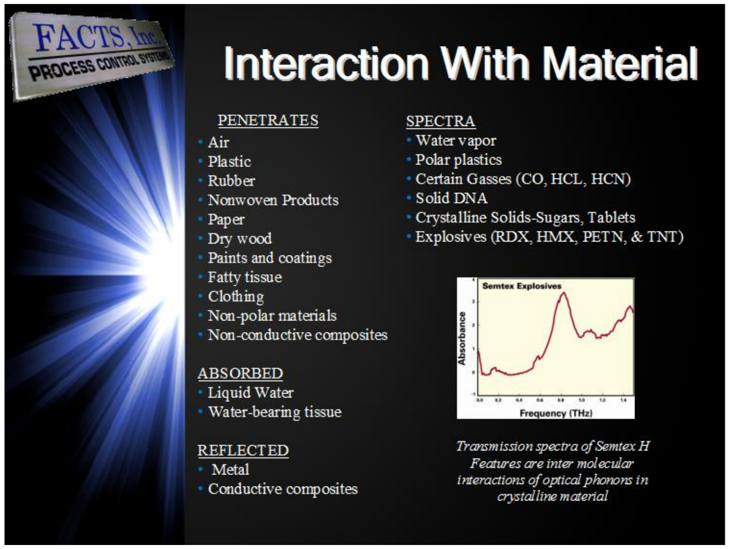


Figure 21

Figure 22 shows a production THz sensor head.

Figure 22

When properly configured and for suitable materials, the THz sensor can make the following measurements concurrently:

- Overall thickness
- Individual layer thickness
- Overall basis weight (gsm)
- Moisture content

Simplistically, the thickness measurement is based on the reflected pulses ToF, the basis weight is determined by the varying ToF of the reflection from a reference plate below the web, and the moisture content is based on the amplitude of the reflected pulses.

Figure 23 is a typical HMI display of the individual layer thickness of a multilayer sheet.

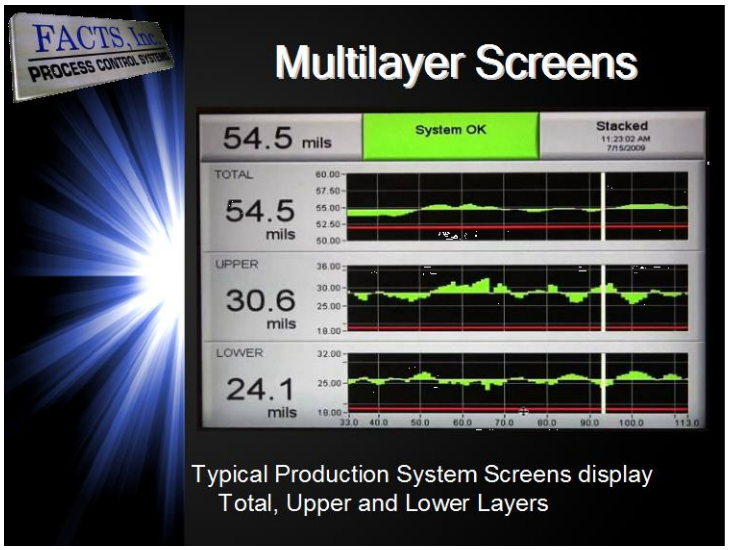


Figure 23

The THz technology is appropriate to a wide range of applications, a few of which are listed in Figure 24.

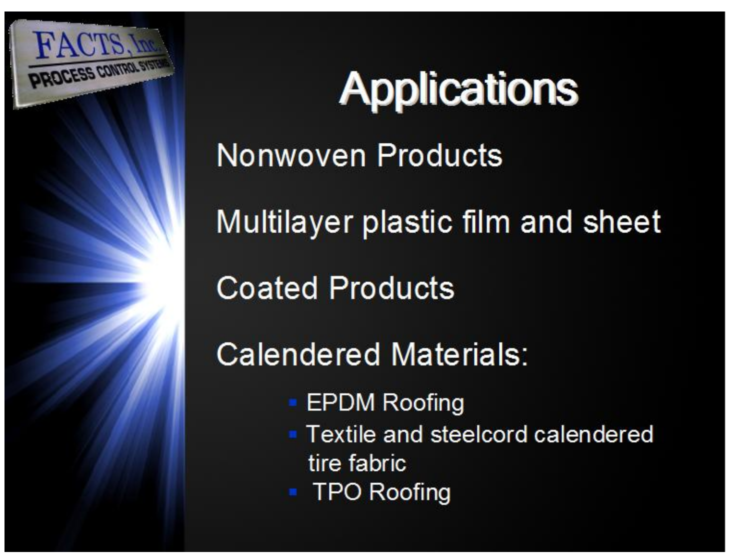


Figure 24

A summary of the Pros and Cons for the THz sensor is provided in Figure 25.

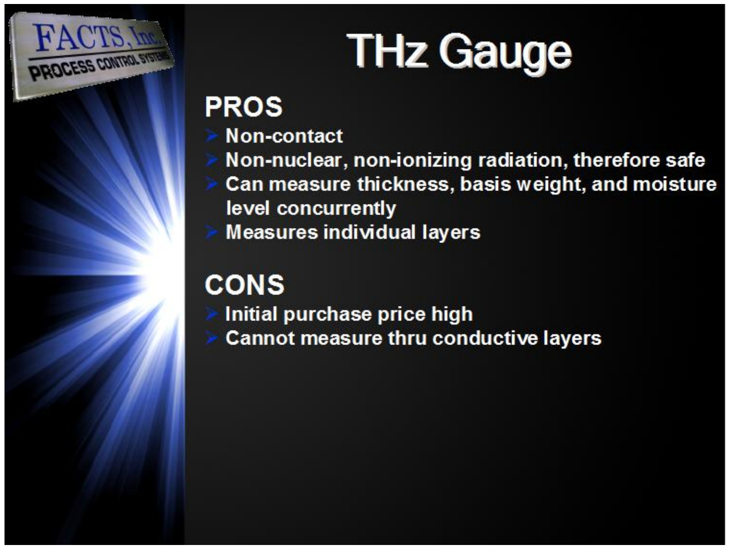


Figure 25

Current THz Applications

Since the THz sensor is such a new technology, a brief review of two current applications follows.

Calendered EPDM Roofing

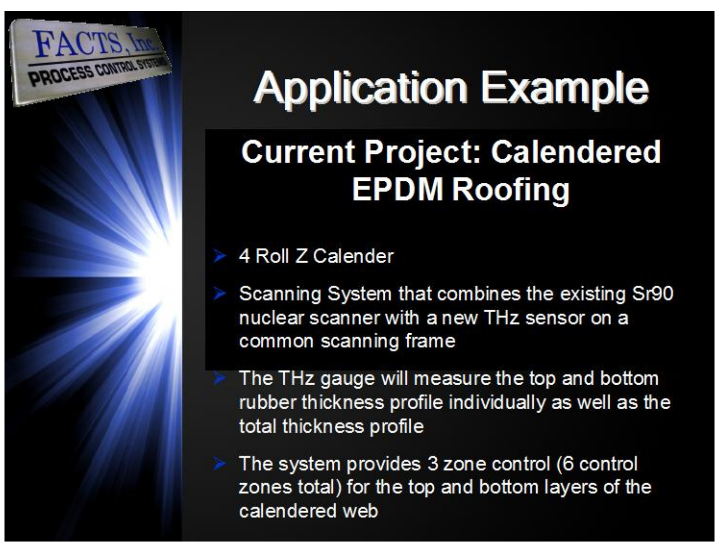


Figure 26

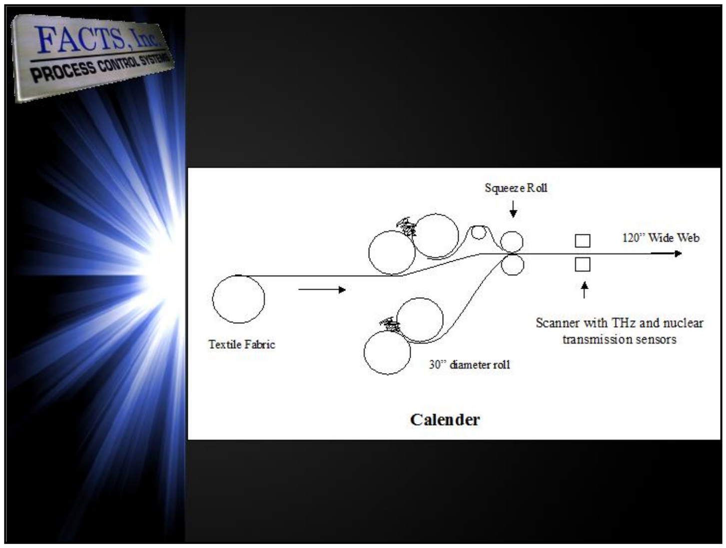


Figure 27

An existing scanning nuclear transmission gauge system is being upgraded to include the THz sensor as shown in Figure 27 above. The upgraded multi-sensor system will provide the following:

- Basis weight profile based on nuclear transmission gauge
- Total web thickness profile – by THz sensor
- Top & bottom thickness profiles – by THz sensor
- Balance or position of the mat within the web – by THz sensor

Asphalt Shingle

Online measurement trials have been undertaken at two different asphalt shingle manufacturing locations. Figure 28 summarized the test set-up.

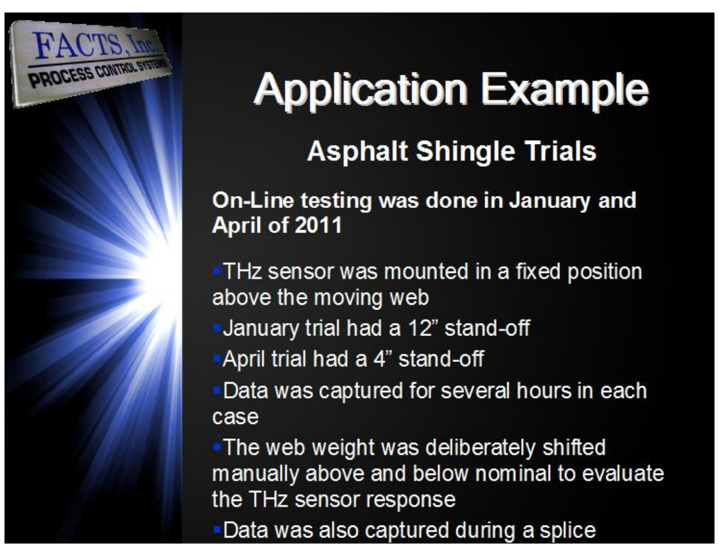


Figure 28

The actual THz sensor is shown in its protective enclosure in Figure 29. Note the shop vac hose that was used to air purge and cool the enclosure during the test. The picture was taken at the end of the test with the cover removed.

Figure 29

Figures 30 and 31 show the sensor in position during the test. The sensor is mounted above the coated mat between the coater and the granule applicator station.

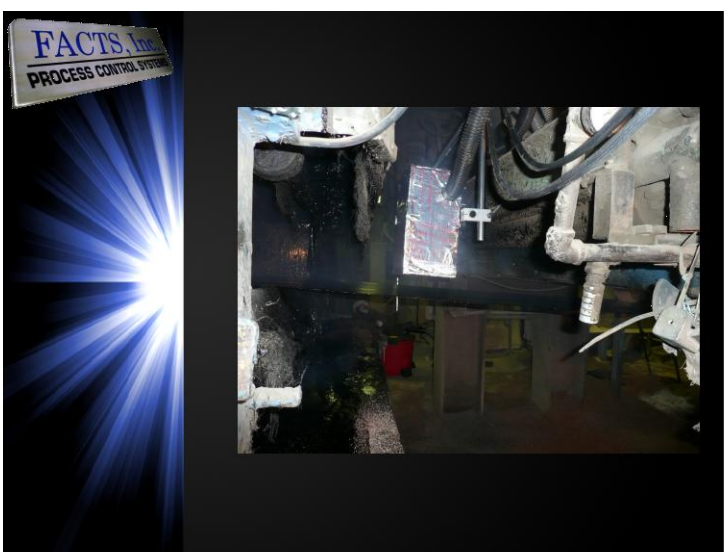


Figure 30

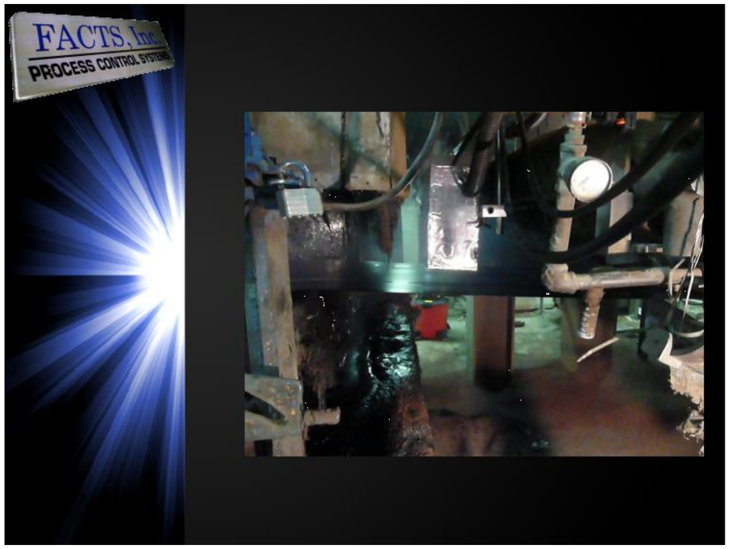


Figure 31

The sensor successfully measured the total thickness of the web without difficulty. Web flutter and fumes had no effect on the measurement. Figure 32 shows the measurement as the weight was manually increased in 2 steps. Figure 33 shows the measurement as a splice goes past at a reduced speed of 350 fpm to more closely examine the splice.

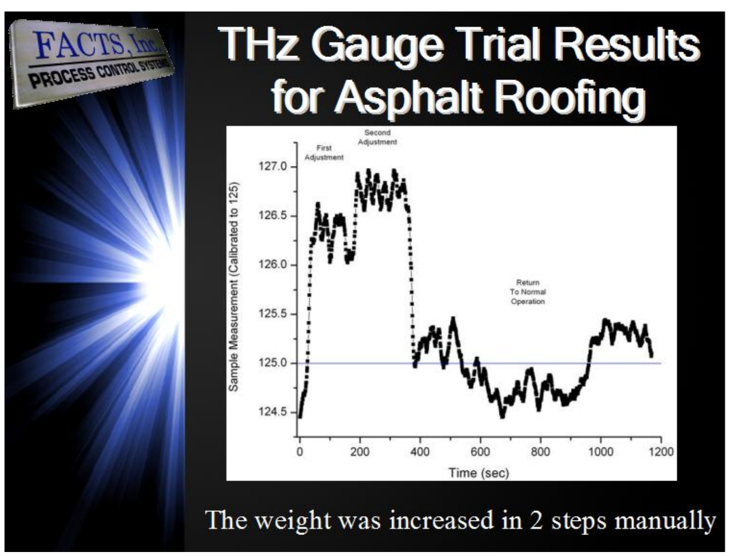


Figure 32

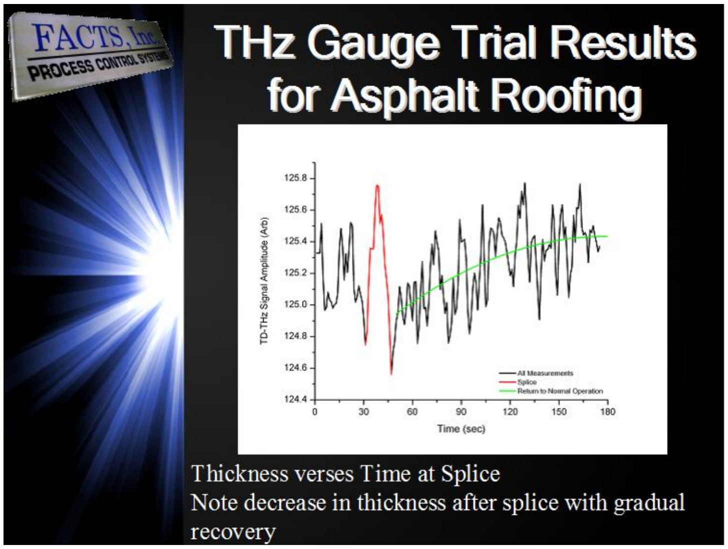


Figure 33

One of the objectives of the trials was to try to measure the asphalt above the mat along with the total web thickness. To date this has not been accomplished due to the poorly defined interface at the top of the mat surface since the mat is fully impregnated with asphalt. The raw data shows promise, but more advanced signal processing will be necessary to make reliably measuring the top of the mat position practical.

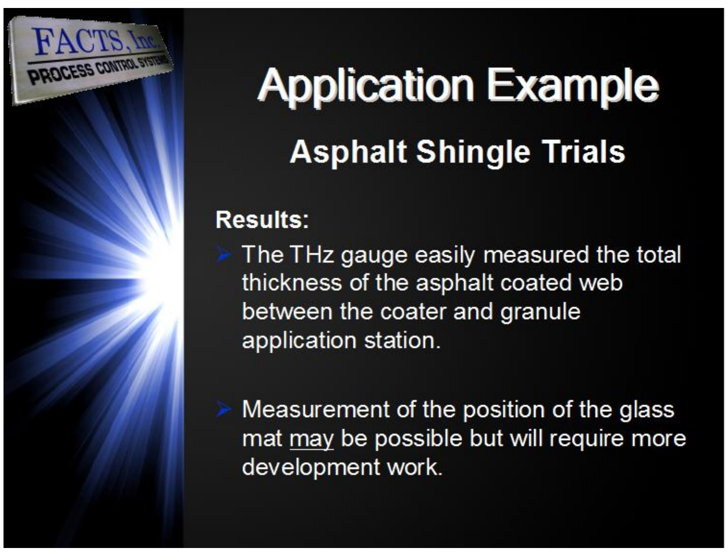


Figure 34

Measurement of the total web thickness between the coater and the granule applicator will provide very fast control updates of the coater. This position also has the advantage of being an essentially flat cross web profile since it is before the granules are applied. Post granule application the web profile is not flat and therefore more difficult to interpret. Additionally, bundle weight can then be used to adjust the granule application and press roll. The THz gauge thus provides an additional control parameter to better control the overall process.