Which Gauge Is Right for Me?
Nuclear versus Non-nuclear

There are three widely established ways to determine asphalt pavement density—nuclear gauge measurements, non-nuclear (electromagnetic) gauge measurements, and core analysis. Because the core analysis method is destructive and the results take time, effective real-time quality control (and sometimes quality assurance testing) often requires use of a nuclear or non-nuclear gauge.

Nuclear moisture density gauges have been used and trusted worldwide for over forty years. The Troxler Model 3400 series gauges are the recognized standard for quality control measurement on soil and asphalt materials. The Troxler Model 4640-B Surface Thin Layer Density Gauge is also widely used for quality control and quality assurance testing on asphalt pavements and respected by the road building industry.

There is increasing market demand, however, for a density measurement device that does not require licensing, record-keeping, and training. The Troxler PaveTracker™ Model 2701-B is the non-nuclear solution that meets this need in the asphalt paving industry.

Because our nuclear and non-nuclear gauges seem to serve the same purpose, it can be somewhat difficult to determine which is the best choice.

The purpose of this document is to assist in make this decision by explaining the technology behind and describing the differences between each type of device.

At a Glance

Pros

Nuclear
- Direct density measurement
- Larger measured volume
- Globally accepted and recognized by most agencies (departments of transportation [DOTs], U.S. Army Corps of Engineers, etc.)
- Soil and asphalt measurement (most models)
- Reliable real-time hot asphalt/cooled asphalt measurement

Non-nuclear
- No radioactive materials license or special safety training, shipping paperwork, monitoring badge, etc., requirements
- No storage requirements or restrictions on crossing state lines
- Lighter
- Fast measurement (two to three seconds)
- Insignificantly better precision (repeatability)
Cons

**Nuclear**
- Licensing requirements
- Heavier

**Non-nuclear**
- Indirect (or relative) density measurement
- Shallower reading
- Smaller measured volume
- Asphalt measurement only (not soil)
- Unreliable cooled/wet material measurement

In Depth

**Technology**
As a starting point, it is important to understand the technology used by the different devices to determine the density that is measured.

A nuclear gauge provides a direct density measurement of the material in the area below it. Its cesium source emits gamma photons that travel through the soil or asphalt. Some of these reach the detector tube inside the gauge’s base and are counted. In denser material fewer gamma photons make it through. (Since dense material contains more atoms in the same space, it deflects more photons.) This is similar to an X-ray of bones or teeth—denser areas appear white in the X-ray image because the film is less exposed.

Instead of directly measuring density, a non-nuclear gauge uses electromagnetic technology to measure the dielectric properties of a mix as it is compacted. As the air voids decrease, the number of dipoles per unit volume, and thus the dielectric constant, increases. This can be equated to a change (or increase) in density if all other properties are uniform.

A non-nuclear gauge cannot use a single calibration for all asphalt mix properties. Therefore, an offset is needed for it to report a realistic density, which generally requires that one or more cores be cut and compared with its result. (The difference between the PaveTracker’s measured density value and the core analysis density value is programmed into the gauge’s software to make future readings more accurate.)

**Measured Volume**
A nuclear gauge’s measured volume is quite a bit larger than that of a non-nuclear gauge.

A nuclear gauge measures to a depth of approximately 3.5 inches, and its footprint is roughly the size and shape of the gauge base (about 9 x 14.5 inches or 228 x 368 mm). The volume of a backscatter measurement, as stated in Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods (ASTM D2950), is 0.0989 ft³.

A non-nuclear gauge measures to a depth of approximately 2 inches (80 mm) under a sensor that is about 6 inches (150 mm) across for a total volume of 0.0286 ft³.

**NOTE:** The depth of a non-nuclear gauge measurement is always two inches or less, and it can vary slightly with the properties of the material. It is important for users to understand this so that the technology can be used properly.
One effective technique for the non-nuclear gauge is to take three to five readings in a small area and average them, which allows measurement of a larger area. Because the readings are very quick (two to three seconds each), this does not present a major inconvenience.

**Precision and Accuracy**

Measurement precision and accuracy are often discussed when comparing nuclear and non-nuclear gauges. The accuracy of a non-nuclear device is determined by offsetting, or adjusting, the measurement results to match an alternative measurement result (often a core). In other words, its readings are not at all accurate until the operator determines this adjustment value and enters it into the gauge. Alternatively, a nuclear gauge will give a reasonably accurate result with no offset, on typical construction materials, because it measures density directly.

The measurement precision, or repeatability, of the two types of gauges is similar, as shown in the table below. In both cases, the difference between the nuclear and non-nuclear devices is under 0.30 lb/ft³. If the asphalt density is 145 lb/ft³, this is just 0.2 percent of the reading. (A 0.2 percent difference is statistically inconsequential. It is equivalent to a sample of 2 in a population of 1,000.)

**Table 1.** Comparison of nuclear and non-nuclear gauge measurement precision (ASTM D2950 and Standard Test Method for Density of Bituminous Paving Mixtures in Place by the Electromagnetic Surface Contact Methods [ASTM D7113]). (These values were computed using a limited number of measurements and operators—they are merely precision estimates.)

<table>
<thead>
<tr>
<th></th>
<th>Nuclear (lb/ft³)</th>
<th>Non-nuclear (lb/ft³)</th>
<th>Difference (lb/ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Lab Precision¹</td>
<td>1.57</td>
<td>1.28</td>
<td>0.29</td>
</tr>
<tr>
<td>Multi-Lab Precision²</td>
<td>1.75</td>
<td>1.47</td>
<td>0.28</td>
</tr>
</tbody>
</table>

¹ One gauge was used by one operator to perform multiple measurements on the same site.
² Multiple units were used by separate operators to perform measurements at the same site.

**Soil and Asphalt Measurement**

Most nuclear gauges can be used on both soil and asphalt. This versatility is often required by companies that monitor many different material types.

**Cooled / Wet Material Measurement**

Nuclear technology is more desirable if density measurements need to be taken on cooled asphalt or asphalt that may have some moisture in or on it. Since the properties of asphalt change slightly after it cools completely, a non-nuclear gauge is best used while the pavement is still warm. In addition, because it measures the dielectric properties of the material, the gauge cannot be used if any significant amount of water is present.

**In Conclusion**

Both nuclear and non-nuclear technologies have advantages and are useful for measuring the density of asphalt materials. The non-nuclear gauge is especially attractive to those who do not desire the radioactive materials license and all that accompanies it. The nuclear gauges have been an accepted technology for many years and can give a good representation of the density of the asphalt with no offset applied. If the differences in the technologies are understood by the user these are both excellent devices for the job.