For years the asphalt industry has been forced to use nuclear density gauges for measuring the quality of the asphalt that has been placed. Nuclear gauges are very hazardous, which is a liability to the operator and dangerous to the general public. Only until the last few years has a viable alternative to the nuclear gauge been made available. An electromagnetic density gauge has been developed that offers a tremendous advantage over the nuclear density gauge.

Compaction Process

Densification of asphalt during the construction of highways is one of the key aspects of the road building process. Hot mix asphalt is a combination of bitumen, stone and sand mixed together in precise volumes and applied at temperatures exceeding three hundred degrees Fahrenheit. Asphalt is a continuous flexible pavement that provides a safe, quiet, durable pavement structure that will last for years if proper densification is achieved. Before
the asphalt has cooled, large compaction rollers compact the asphalt into a continuous mass designed to be impermeable to water infiltration. During the compaction process, direction is given to the roller operators to ensure that proper rolling techniques are used to ensure the road will meet strict density requirements specified by state agencies or municipalities. Overall quality and performance of the final asphalt structure depends on the individuals and their quality control instrumentation to monitor the compaction process and give directions to the roller operators if the specifications are not being met.

**Density Testing**

During the last forty years the quality control instrumentation of choice has been a non-destructive measurement device that uses nuclear isotopes to measure compaction and is known as a nuclear density gauge. There are major safety considerations when using these devices due to the exposure to radiation and the possible damage and loss during operation.

In addition to the non-destructive tests, highway contractors are required to perform a destructive test that is required to verify the density gauges for the final approval before they are paid for the project. This test is based on techniques founded hundreds of years ago, and involves extracting a core sample and using Archimedes principle of water displacement to measure pavement density. This water displacement test will be the test of record for the project and will be performed at random intervals during the construction process.

**Nuclear Gauge Hazards**

There are inherent hazards in operating nuclear gauges compared to electromagnetic gauges.

Nuclear gauges contain two radioactive isotopes, a gamma photon emitter Cesium 137 used to measure density, where the photons act very similar to x-rays and an alpha and neutron emitter Americium 241-Beryllium for measuring moisture through neutron thermalization where the neutrons interact with any hydrogen bearing material from construction material to human flesh. Electromagnetic density gauges emit an electromagnetic field using a transmitter and receiver at one megahertz. This frequency falls in the microwave range and is projected into the construction material.

Safely operating a nuclear density gauge is very problematic due to the decaying nuclear isotopes,
which emit ionizing radiation. There is no way to turn off a radioactive isotope and the two sources used in the nuclear gauges last for sixty-five and four hundred and fifty-six years for the Cesium-137 and Americium 241-Beryllium, respectively. The radioactive material in a nuclear gauge emits ionizing radiation twenty-four hours a day, seven days a week that can penetrate human skin and concrete. Electromagnetic density gauges emit a signal into the construction material, which travels a matter of inches and can be turned off when not in use, unlike the nuclear gauge.

Transportation and Security

Radiation exposure to the nuclear gauge operator and the potential exposure to the general public require that the Nuclear Regulatory Commission regulate nuclear gauges. Owning nuclear gauges becomes a very involved process that requires special radioactive materials licenses, constant radiation exposure monitoring of personnel, and required safety training. The signals emitted by the electromagnetic gauges pose no hazard to the operator or general public and require no materials licensing, exposure monitoring, or safety training.

Transportation of the nuclear gauge is traditionally done in open bed pick-up trucks or the trunks of cars. There are very strict rules that mandate how these gauges are transported. Incident reports from the Nuclear Regulatory Commission show that vehicle accidents and vehicle theft are common causes of loss and damage to nuclear gauges. (NRC 1998) The Nuclear Regulatory Commission reported that from February 1996 through August 1997 that 33 thefts...
of nuclear gauges occurred. Twenty-one of the thefts involved devices stored in vehicles. (NRC 1998) Additional disclosures from the NRC have indicated that an average of 300 reports a year of small amounts of radioactive materials missing from construction sites, and hospitals. (USA Today 2002) Electromagnetic gauges have no special requirements for transport or storage and there are no statistics maintained on loss or theft.

Disposal is Difficult

Environmental impact issues are one of the greatest concerns of regulatory agencies and the materials licenses require a plan for storing, transporting, and protecting workers and decommissioning and disposing of nuclear gauges. Radioactive source manufacturers guarantee the containment capsules that house the radioactive material for only fifteen years. The isotopes used in the nuclear gauges are very hazardous to individuals as well as the environment. There are only a few locations in the United States that will store or dispose of these isotopes. There is only one facility in the United States that will take the neutron sources for permanent storage. Because the neutron radiation will last over four hundred years there is no disposal of these sources. Los Alamos Laboratories in New Mexico has only recently opened for the storage of these isotopes. Gamma sources may be turned over to authorized radioactive material landfills for burial, one facility in Washington State has just started turning these isotopes away. Electromagnetic gauges require no special handling or disposal.

Because the nuclear gauges contain radioactive isotopes they are of interest for their use as a potential weapon. Radiological dispersal devices or “Dirty Bombs” are terms that have been adopted to describe the use of nuclear density gauges as weapons. The radioactive material could be easily removed, made into a powder, attached to a conventional explosive and detonated on or around a target. The radioactive material would then be dispersed into the air and cause anything it came in contact with to be contaminated. Human fatalities would occur when the airborne isotopes are inhaled. Major disruption of commerce would occur due to the panic inspired by the release of the radioactive material and the decontamination process involved. (USA Today 2002) The media has only picked up on the potential of terrorists using these isotopes as “dirty bombs”, in a little known IAEA (International Atomic Energy Association) report in 1977 and a resurfacing of the same report in 1998 did it become public that there is the potential to use Am-241 in a nuclear weapon. Am-241 is a by-product during the irradiation of fuel in nuclear reactors that use Pu-241. Am-241 is commonly separated in small amounts for use in smoke detectors, neutron generators, portable density gauges and other research activities. “Separated in larger amounts could be enough for making large numbers of nuclear weapons and could grow at a rate of 10 tons per year.” (TCNC Newsletter 99-3) As reported by National Public Radio in 1998 in an acknowledgement to the severity of the potential use of Am-241 as weapons grade radioactive material, the United States government officially recognized the potential by requesting that the former Soviet block nations stop selling Am-241 on the world market. The US government acknowledged that during the Manhattan project that they were successful in creating a nuclear weapon with Am-241. Conversely, electromagnetic density gauges use electricity to measure density and there are no applications for the use of this device as an explosive-type weapon.

“Radiological dispersal devices or ‘Dirty Bombs’ are terms that have been adopted to describe the use of nuclear density gauges as weapons.”
**Electromagnetic Gauges Faster, Safer**

There are many advantages of using electromagnetic gauges over nuclear for measuring asphalt density. The statistical precision of nuclear gauges or repeatability of one density reading to another is poor compared to electromagnetic gauges. Nuclear gauges use a gamma source and Geiger Mueller detector tubes to measure density. The radiological event utilized in this process is the Compton effect, basically bouncing a gamma photon off an orbital electron of the material under test and measuring the energy left in the photon by the detection tube. Statistically the chances of reading the same data in the same place using the Compton or backscatter effect is very low. (Troxler Laboratories 1998, Gollnick 94) Alternatively the electromagnetic density gauge uses electromagnetic energy directed into the asphalt and measures the dielectric properties of the material. This field is three-dimensional, projected into the material by a transmitter and measured by a receiver and works on a direct reading from the material properties of the asphalt. Statistically, the electromagnetic measurement technique is much more reliable and precise. (TransTech Systems 2001)

**Nuclear Readings Slow Process**

Because of the nuclear gauge measurement technique, the most accurate individual readings take more than four minutes. For optimal performance, the manufacturer recommends multiple four-minute readings. When working on three hundred degree asphalt for such long intervals, the nuclear gauge electronics become overheated and will suffer premature component failures over the life of the equipment. Electromagnetic gauges use a continuous density output for instantaneous measurements. Single readings similar to the nuclear gauge require only five seconds compared to the four minutes for the nuclear gauges. The electromagnetic gauge can profile the entire asphalt surface in a matter of minutes while the nuclear gauge would take hours limiting the exposure to elevated temperatures and ensuring a full quality control evaluation of the entire asphalt surface.

Nuclear gauges contain lead and tungsten, which are used as protective shielding, making the gauges very heavy compared to electromagnetic gauges. The nuclear gauges weigh almost forty-five pounds, add another forty for the required transport case and you have a total weight of about 100 pounds. The electromagnetic gauge weighs less than fifteen pounds and the optional case adds only another fifteen pounds for a total of thirty pounds. The outside dimensions of the nuclear gauge transport case make it twice the size of the electromagnetic case and regulations require that the nuclear gauge not be transported in the passenger compartment of a vehicle.
Electromagnetic gauges are lightweight compared to nuclear gauges and are easily and safely transported in passenger vehicles.

Nuclear gauges have many mechanical parts due to the shielding requirements of the isotopes and have very heavy inefficient battery systems. Because of the nuclear gauges being transported in open trucks, the exposure to adverse weather results in poor reliability, requiring frequent repairs. Electromagnetic gauges have few moving parts compared to nuclear gauges, and very efficient, lightweight power systems using state-of-the-art batteries and charging systems. The electronic systems require little preventive and corrective maintenance.

Nuclear gauges require complex licenses, required safety training, personal monitoring devices, annual calibration and maintenance fees and expensive transportation costs. Initial and annual licensing fees for nuclear gauges can be very expensive. Required safety training and annual renewal fees are charged for each operator. Personal monitoring devices, known as TLDs, (Thermoluminescent Dosimeters), are required for all operators and employees working near the radioactive gauges. According to estimates from a company supplying these services, costs for a single individual are approximately 5% of the purchase cost of the gauge per year. A major manufacturer of nuclear-based density gauges reports average calibration fees for nuclear gauges of more than three times that of the PQI’s calibration fee. Corrective action for the nuclear gauge is also extremely expensive. Returning nuclear gauges for service requires complicated forms and costly transport fees. Specific carriers must transport nuclear gauges; many common carriers choose not to transport these hazardous gauges. Electromagnetic gauges have a clear advantage over nuclear gauges with respect to owning-operating costs and have no shipping restrictions.

Terrorism Potential
In addition to the dirty bomb article in USA Today mentioned above, here are two of a growing list of news articles on nuclear gauges that have gone missing:

Raleigh TV Station Reports Nuclear Gauge Missing from Durham, North Carolina Company
In late April of 2005, TV station WRAL of Raleigh, North Carolina broke news that the state's Division of Environmental Health’s Radiation Protection Section had reported that a device containing radioactive material had gone missing from CTL Engineering in Durham, North Carolina.

The company reported the theft of a Troxler Model 3440, which is used to measure the density of asphalt, soil, aggregate or concrete on construction sites. The device weighs about 30 pounds and it has caution decals on it that indicate that it includes a radioactive device.

The report goes on to state that the loss of the gauge poses no immediate threat to health or safety unless the source is handled improperly or damaged. Its Cesium-137 and Americium 241 sources are sealed in stainless steel capsules.

Local 6 News of Orlando, Florida Reports Nuclear Gauge Stolen
On May 2, 2005, WKMG-TV reported that a nuclear density test gauge was stolen from a construction site in Daytona Beach. The gauge is listed on the federal government’s watch list. The theft was reported to the Atomic Regulatory Commission as it contains radioactive sources.

The report continues that the gauge is a common piece of equipment on Florida jobsites and is used to measure the density of soil. It is manufactured by Troxler Electronic Labs of Raleigh, North Carolina. In addition to its intended uses, the gauge sources could also be used for the wrong reasons, including terrorism.

Conclusion
Electromagnetic asphalt density gauges offer portability, accuracy, safety, and low owning-operating costs compared to the nuclear asphalt density gauges. With the potential use of the nuclear gauges for weapons, and the numerous accidents involving gauges and their loss, this presents a singularly good case for the substitution of nuclear

“The electromagnetic gauge is a viable alternative to the nuclear density gauge for quality control and quality assurance on the construction of asphalt pavements.”
gauges with the electromagnetic gauge. This case is bolstered by an electronically advanced measurement system that is fast and accurate. The electromagnetic gauge is a viable alternative to the nuclear density gauge for quality control and quality assurance on the construction of asphalt pavements.

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About the Author

Alan Gilbert is a Manager with TransTech Systems. With over 20 years of technical applications knowledge, including his service as a Systems Technician in the U.S. Navy, Gilbert has represented leading nuclear gauge laboratories in Product Management, Technical Training Coordination, and Technical Support. He has a vast working knowledge of laboratory procedures and field paving techniques using both nuclear and non-nuclear quality control of construction materials.
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