# 2.19. DUAL ENERGY X-RAY INTROSCOPES FOR SCREENING BAGGAGE AND LUGGAGE OF AIR PASSENGERS

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Nowadays, X-ray systems are used worldwide for inspecting baggage and containers to identify concealed weapons and illicit substances. X-ray systems provide an unique ability to detail images nondestructively. An experienced operator of such systems gleans a wealth of information from X-ray images and recognizes a wide variety of objects, both dangerous and innocuous, from the projected image. This is especially true for metallic objects that stand out clearly from the background contents. Owing to their organic makeup, many explosives do not have a distinctive appearance when imaged and might be easily overlooked. The last 15 years has seen the application of automated, computerized analysis of X-ray images for improved security.

First-generation equipment featured a side-shooting X-ray source collimated into a broad cone beam, then transmitted through baggage and finally sensed by a fluoroscopic screen. The progress in electronics leaded to the next generation of X-ray inspection system. These units featured a side-shooting fan beam of X-rays incident on an extended array of scintillators optically coupled to photodiodes or phototransistors. The resulting low-level electric currents are then amplified, integrated, and electronically sampled and digitized. Since the end of 80s X-ray systems were enhanced by providing dual-energy data. The data were extracted from two adjacent detector arrays having thickness and filtration designed to respond respectively to the higher and lower energy parts of the incident X-ray spectrum. Atomic number for each pixel was coded in color, while attenuation was still displayed through intensity. Since 1990 several companies offered systems with automatic threat recognition options. They relays on precision measurements of effective atomic number (Zeff). In that time it became obvious that knowledge of only Zeff is not enough. Systems that combines different equipment, based on different physical bases and CT technologies came into the considerations.

X-ray inspection of baggage can be divided into a number of technologies, depending on the physical principles employed and whether computer automation used for detection. Many of these technological systems are in common use at airports, government buildings, and other security checkpoints. Conventional X-ray systems are used in conjunction with operators who view the images looking for threats or illicit substances in the X-ray image. The term generally refers to relatively low kilovoltage systems (less than around 150 kVp) and is typically used for inspection of carry-on items at airports and public buildings, incoming parcels to businesses and agencies, and items shipped through the mail or via other carrier.

Dual-energy systems provide two transmission images of the inspected item, taken at different X-ray energy ranges, designated HI and LO. The attenuations from these measurements allow determination of the effective atomic number, Zeff. A number of different methods have been employed to obtain the HI and LO images. The so-called true dual-energy systems actually vary the X-ray source spectrum. This is accomplished either by using two separate imaging systems operated at different energies or by rapidly alternating the kVp in a single view. Filtered dual-energy systems, use a single-energy spectrum but employ detectors that are responsive to different parts of this spectrum. This is implemented by varying the type, thickness, and filtration of the detectors. Generally, the true dual-energy systems are capable of better discrimination of Zeff.

Multi-view/CT systems make use of several views the baggage at differing orientations. They provide a large amount of detailed information about each individual object packed in articles of luggage. Density estimation increases detectability of explosive substances.

X-ray scatter information used for baggage inspection, often as a means to supplement transmission imaging. X-rays are scattered primarily by Compton (incoherent) interactions. The technique makes use of the difference in scattering behavior between organic and metallic materials. Low-Z materials scatter X-rays quite effectively, whereas higher Z material preferentially absorbs X-rays via photoelectric absorption and hence show less scatter.

Most explosives have a crystalline structure. Because the crystals are small and randomly orientated, the structure is sometimes referred to as polycrystalline. These crystals exhibit a strong coherent scatter at certain angles that depend on the X-ray energy and the crystal lattice spacing. This coherent scatter (also called diffraction) is a property of the crystal lattice and is unrelated to coherent scatter that occurs off atomic nuclei. This is the principles of so called coherent X-ray scatter systems.

Nowadays automatic baggage scanning systems for the detection of explosives are integrated into baggage handling systems. Typically different levels of screening are installed. Starting with fast level 1 units and slower systems or human operators at the subsequent levels