STUDIA UNIVERSITATIS BABEŞ-BOLYAI, CHEMIA, XLVI, 1-2, 2001

SCREENING TECHNOLOGIES FOR AVIATION SECURITY

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ABSTRACT. Ensuring the security of the air travel system is currently a monumental task. Air carriers are the first responsible for insuring and maintaining air travel security; a major part of this responsibility implies developing and using of a security program that includes screening all passengers and their baggages. Operationally speaking, it means that air carriers have to purchase the appropriate equipment, to design and setup checkpoints covering access to their flights, and to hire and train the personnel needed to operate these equipments and checkpoints. This paper's goal is to provide an overview to the technologies used for security screening in the civil aviation. Imaging technologies are best represented by X-ray methods, while most promising trace detection technology seems to be ion mobility spectrometry.

1. Introduction

Ensuring the safety of the air travel system is definitely a huge and challenging task. In USA only this involves the screening of more than 1.5 million passengers (with their luggage) every day, for the presence of metallic weapons and other dangerous materials **[1,2]**. As a response to these complex security requirements, the airport authorities have to examine the new technologies designed to improve the effectiveness of screening procedures and to implement other technologies able to detect not only metallic weapons but also other types of dangerous objects and substances (e.g. plastic explosives). There is a stringent need for the implementation of new, automated passenger screening methods, which are used to detect threats such as concealed weapons and explosives being carried by passengers **[1]**, but also for narcotics smuggling detection.

It is a well established fact that the level of tolerance demonstrated by the traveling public (concerning perceived health risk, lack of privacy, delays and so forth) is proportional to the perception of the threat's severity. From this point of view, more expensive screening equipment and more intrusive screening techniques will be accepted only at higher threat levels. It is interesting to note also at this point that screening technologies ensure detection of threat objects and materials, but they also function as deterrents (the effectiveness as a deterrent depends strongly on perceived, rather than real, reliability and fidelity of the system).

2. Passenger screening

There is a dilemma in passenger screening: how to provide an effective screening level at a reasonable cost and for all threat levels. Performances of the security systems used in commercial aviation security must be assessed to determine both their effectiveness (the capability to detect threat objects, which in turn is dependent on the technology used) and suitability (the capability of a system to operate with fewest undesirable parameters, such as high radiation levels) **[3]**. These performances have to be evaluated continually, and this specific process should be designed to provide an effective feed-back that allow air carriers and instrument manufacturers to make the desired improvements of the system. Today the compliance of security systems with the standards set by the FAA (Federal Aviation Administration - USA) is considered the minimum acceptable level of performance.

This paper has the following goals:

- to review the potential automated instrumental methods currently under consideration for passenger screening applications
- to evaluate aspects of each method that may cause concerns over health risks, privacy and traveler comfort
- to consider ways in which the above mentioned methods can be implemented to maintain a high level of effectiveness, together with minimizing health risks and increasing of public acceptance
- to examine the key factors that could affect airport implementation of such technologies
- to suggest some alternate screening methods for those passengers who wish or need to avoid the automated systems.

The ideal passenger screening technology should require the following specifications **[3]**:

- detection of both metallic and non-metallic threat items in real time (less than 10 seconds)
- a high degree of accuracy – including a high detection rate together with a low false-alarm rate
- giving the operator a significant amount of information, in an appropriate format, to allow for the speedy and accurate resolution alarms.

It must be emphasized here that current passenger security screening requirements and procedures were developed in response to the increase in airplane hijackings prior to 1972 **[2]**. However, because of increasing attractiveness of aircraft as terrorist targets, the need to improve the capabilities of existing airport security screening systems and processes was recognized. These improvements include:

- enhancing the ability of metal-detection portals to operate effectively in an electrical noisy environment
- providing better information to security personnel on the type and location of potential weapons/threats on individuals
- increasing the detection capabilities of existing systems, by adding the ability to detect a broader spectrum of metals, alloys, plastic explosives, and any other threat materials.

It was found that trace detection technologies, which detect the explosives by interaction with their vapors (or particles), can be used to supplement metal detection technologies to build more comprehensive security systems. By this way metal-detection portals could be replaced by improved systems that reveal the objects concealed under clothings and enable both metallic and non-metallic threat objects identification. The conclusion is that these new detection technologies have technical and analytical features that strengthen their detection capabilities.

However, the acceptance or the rejection of a given technology both by the people who use it (e.g., air carriers companies and airport operators) and the people affected by it (e.g., passengers and aircraft crews) is clearly as important as its performances. For instance, air carriers will manifest strong opposition to the implementation of any technology, no matter how perfect it is, if this technology is unacceptable to the traveling people for various reasons: health reasons, legal and privacy reasons, operational problems and convenience.

The key issues in the passenger screening requirements are:

- ability to find passengers carrying metallic weapons
- detection of explosives, plastic explosives and any other threat materials
- reliability of the system, which is related to consistency in the performances of that system
- fidelity of the system (how accurately the output from the system represents the item to be examined)
- reliability issues regarding operating personnel.

In Table 1 the responsibilities of all factors involved in passenger screening are described, as in the American FAA (Federal Aviation Administration) specifications **[2,3]**.

Table 1.

Responsibilities for passenger screening

Entity	*Responsibility*	*Action*
Air carriers	Provide secure travel	- maintain security program - screen passengers and carry-on baggage - secure baggages/cargo - protect/secure aircraft
Airports	Provide secure operating environment	- maintain security program - protect operations area - provide law enforcement support
Civil aviation authority	Provide the administrative & procedural guidance	- identify/analyze threats - establish requirements/procedures - coordinate crisis situations - provide technical assistance - enforce regulations
Passengers	Cooperate	- fund carrier & airport security via travel tickets purchase

3. Technological improvements

The biggest problem concerning the current passenger screening technologies and procedures is that they don't provide the operator with specific and clear information about the nature and location of the potential threat items, so all the new technologies used in aviation security have to identify and locate this kind of dangerous objects by addressing in the same time the following concerns:

- Convenience (manifested by the smallest possible delay possible for the passengers).
- Respect of the passengers' privacy.
- Legal aspects (for example, the information about non-threat items can be minimized by simply limiting the search area; on the same time, there is a stringent need to discover some non-threat but illegal items, such as narcotics carried by a passenger).

The advanced technologies used in the future for the passenger screening can be classified in two large categories:

1. *Imaging technologies* – which can "see through" clothes and consequently produce an image of the human body plus the objects carried on. It must be emphasized here that all these images yield various amounts of details (depending on the technology used to generate it), but none of them is of photographic quality; as a matter of fact, operators are always needed to view and interpret the images. Imaging technologies can be further classified as well in *active* and *passive* technologies. In the passive screening technologies, the natural radiation emitted by the human body is detected and analyzed, so this type of technology minimize the risks due to the radiations. Active imaging technologies suppose the irradiation of an individual with radiation (either X-rays or microwaves) and then the radiation scattered from the body is analyzed. In both imaging procedures, objects (e.g., metallic weapons or explosives) that emit or scatter radiation differently from the human body will appear different from the background on the image. It was concluded that the images produced by using these techniques are of sufficient high quality to be effective in passenger screening. Another issue is the possible health effects due to the radiation used in active imaging technologies, but we have to specify that these levels of radiation exposure used for screening are by far insignificant when compared with those experienced during many other common activities.
2. *Trace-Detection Technologies*, which physically collect samples of air or material (small particles) from the clothes, bodies or baggage of a passenger and use these samples to detect the presence of a dangerous material. Sample collection is here the key step of an analysis, and it supposes either sampling the air around a person, or touching/swapping the individuals to remove the particles of materials (e.g., plastic explosives) from them or their hand-carried baggages, electronic devices and boarding cards. Unlike the imaging technologies,

where the technologies themselves are already quite mature and the specific equipment is consolidated, accepted and commercially available, many trace-detection techniques are still in a development and assessment phase.

3.1. Imaging technologies

These technologies can detect metallic and nonmetallic weapons, explosives and other contraband material concealed under multiple layers of clothing, by creating images that can be examined to discern these items. Basically, there is not involved any physical contact with the passenger **[3,4]**.

Imaging methods are well established and already used for a wide variety of security applications, such as screening of visitors in prisons or screening the employees at shops' exit to deter thefts. In Table 2 the ways of implementation of imaging technologies in commercial aviation security are described.

Table 2.

Screening technologies based on imaging

Detection technology	*Uses*	*Comments*
Millimeter waves	Portals	- Requires more than a single view
	Wall units	- Requires more than a single view
	Enclosed spaces	- Could provide a 360º view
X-Rays	Portals	- Requires more than a single view
	Enclosed spaces	- Could provide a 360º view

These screening systems generate television-like digital images that can be evaluated by image processing and analysis methods. Images are viewed by an operator trained to identify potential threat objects in these images. Sometimes it is used a special image enhancing software that highlights some unusual features; advanced computed tomography (CT) X-ray systems are good examples for this kind of investigation.

Neutron technologies are also considered for the detection of explosives; thermal neutron analysis and fast (or pulsed fast) neutron analysis are the best known.

Although these techniques cannot detect objects concealed inside the human body or in skin flaps, they are widely considered and used for airport passenger screening because their capability to allow the screening of a wide variety of materials.

3.1.1. Passive and active millimeter-wave imaging

This technology operates in the millimeter-wave range (near 100 GHz) of the electromagnetic spectrum. Passive millimeter-wave imaging is based on the principle that any object (which has not 0 K) emits electromagnetic radiation at all wavelengths. By using an appropriate receiver, this radiation can be detected to produce an image. An important advantage of passive millimeter-wave imaging technique is exactly its ability to provide the image by simply gathering only the radiation emitted naturally from the human body, without using any artificial radiation; thus, practically no health risks are associated to this technology.

The display methods of the passive millimeter-wave imaging technique are similar to those used for X-ray methods.

Passive millimeter-wave imaging produces screening images of various items carried by passengers: wallets, keys, belts, pocket knives, other common and non-threatening items, but also hidden weapons. An image-analysis software was developed to facilitate interpretation of the images, but finally current technology requires a decision from the human operator **[3,4]**.

Active millimeter-wave imaging systems work as short-range radar devices that project a narrow beam against the target (traveler's body) then detect the reflected radiation. This beam is scanned from head to toes to produce a complete image of that person.

However, the popular perception of the dangers of microwave radiation may cause concerns about this technique.

3.1.2. Active X-ray imaging

This technology uses low-energy, low-intensity X-rays reflected from the subject scanned to create an image. These images are then interpreted to detect the presence of metallic and non-metallic weapons and explosives concealed under multiple layers of clothing or in baggage **[3,5]**.

As in passive imaging systems, the presence of non-threat items complicate the images produced by X-ray imaging systems, making them difficult to analyze and interpret.

Concerning the possible health effects due to the ionizing radiation used in screening systems, it should be pointed out that these effects are negligible (0.003 mrem per exposure at X-ray security screening) comparing with, for example, 5 mrem for a transcontinental air travel (one way trip), 50...200 mrem for annual radon exposure and also some medical X-ray exposures, 5,000 mrem which is the maximum allowable annual radiation exposure to workers and the huge amount of 500,000 for the acute radiation effects or even 5,000,000 for radiation therapy (total treatment) for cancer **[6,7]**. The effects of ionizing radiation on the pregnancy are significant (developmental anomalies and mental retardation) only when the radiation dose exceeds 10,000...20,000 mrem. Also, the passengers who wear pacemakers are not affected by the radiation exposure in passenger screening systems, because pacemaker malfunction occurs only when radiation doses exceed 1,000,000 mrem.

3.1.3. Evaluation of imaging technologies

Factors that influence the usefulness of these technologies are:

- the effectiveness of imaging systems depends on how clear is the image produced; in other words, on how distinct can be made the threat items (such as metallic weapons) on the body background
- although the imaging technologies cannot create a photographic image, they can produce images that can be interpreted by trained operators

- all current imaging techniques require human operators to view, analyze and interpret the complex images produced and to identify the anomalous (threat) items more efficiently than any available software; as a matter of fact, the great variety of human body shapes and sizes complicates the automated image interpretation
- the amount of time necessary to obtain enough information to make a decision affects also the effectiveness of imaging technologies: in screening passengers, the processing time for one person is about 6 seconds
- there are situations when two-sides (front and back) images are taken, to provide a 360° view.

3.2. Trace-detection technologies

As it was already highlighted above, trace-detection technologies are based on the direct chemical identification of either particles of explosive materials or vapor-containing explosive materials. Thus, the presence or the absence of a bomb is confirmed by the presence/absence of explosives' particulate matter or explosives' vapors **[5]**.

One may observe that the fundamental difference between trace-detection, imaging and electromagnetic techniques is that in trace-detection we must have a physical transport of a sample containing explosive (of course in concentrations exceeding the detection limit) to the instrument.

Trace-detection techniques cannot be used to detect the presence of metallic weapons, as imaging technologies currently do.

The two distinct steps occurring in trace-detection are *sample collection* and *chemical identification*. Obviously, to enable identification of explosives both steps have to function well simultaneously. We can observe also that the sample collection phase is the main procedural point of contact between this technology and the passengers to be screened. Potential applications of trace-detection equipment in airports were summarized in Table 3.

Table 3.

Applications of the screening technologies based on trace-detection

Implemented as...	*Comments*
Portal screening - noncontact	Involves high-volume air flows to gather vapors or to dislodge particles from surfaces.
Portal screening - contact	Passenger opens the portal's doors with hands. Passenger passes through a portal lined with brushes.
Hand-wand device - noncontact	Involves high-volume air flows to gather vapors or to dislodge particles adhering to surfaces.
Canine screening - noncontact	Technology currently in use.
Boarding card scanner - contact	Boarding card is scanned for particles of explosive materials, after handling by passenger.

Concerning the possible health effects, it must be kept in the mind that trace-detection technologies for passenger screening may involve person to person contact or direct contact between an individual and the detection equipment. Of course, these personal contacts could be a vehicle for transmitting various microbial diseases (bacterial, fungal, and viral) from one individual to another, through inhalation or ingestion of disease-causing microorganisms, direct contact with individuals, through wounds and cuts. However, the probability of transmitting diseases as a direct consequence of using trace-detection systems appears to be insignificant in comparison to other more common disease transmission scenarios (like using public washroom facilities). Equipment should be designed to allow frequent cleaning to minimize passenger to passenger disease transmission **[3]**.

3.2.1. Sample collection

Explosives can be transported from the passenger screened to the trace-detection equipment as vapors or as solid microparticles. We shall remind here that the initial efforts in the development stages of trace-detection techniques were focused toward collection and preconcentration of vapors around a person or a baggage. However, because most modern explosives (especially plastic high explosive materials) have extremely low vapor pressures and consequently they don't emit practically vapors at room temperature, the focus has expanded toward the detection of particulates of explosives, on the skin and other surfaces (such as clothes, baggages).

So, if one has to detect traces of explosives material these traces must be concentrated from the air sample (vapor technologies) or dislodged from a substrate (particulate technologies). The result is that in vapor technologies we have to collect very large amounts of air, and in particle technologies the microparticles of explosives must be removed from the surfaces to which are adhering.

Both approaches have their strengths and weaknesses, which in turn depend on the type of explosive screened **[3,5]**. From this specific point of view, vapor technologies are much more effective for detecting those explosives that possess high vapor pressures, while particulate technologies are used for explosives with low and very low vapor pressures (for instance, military plastic high explosives).

Samples can be taken by using 2 methods:

- by passing the subject (the passenger) through a portal
- by passing a hand-wand device over the subject.

Each method can be implemented as a contact or non-contact technique (see Table 3 above):

- In contact portal sampling, the passenger walks through the portal by rubbing against brushes and paddles; generally speaking, contact methods' goal is to gather particles of explosive material from the hands/clothing of a subject.
- In non-contact portal systems, an air flow passes over the passenger when he walks through the portal; these systems can use the air stream either to dislodge particles or to collect a sample of vapors.

It is obvious that even if the use of a hand-wand device is an efficient sample collection technique, it is also much more labor intensive and time consuming than collecting the same samples using an automated portal, which is very similar with common portals used to detect metals.

A conclusion which is arising from the ideas stated above is the following: due to the difficulties encountered in extracting explosive vapors from large volumes of air or to gather particles of explosives from a huge variety of materials, it is not surprising that we don't have yet currently an universal adopted sampling technique **[5]**. For example, there are many companies which develop such systems used to dislodge the material mechanically either with air flows (air brushes) or air vacuum devices, but we must underline that none of the sampling techniques was universally effective under all conditions. As a consequence, this lack of a specific sampling approach generates difficulties in discussing about a generic trace method, and also creates serious problems in designing a standard protocol (for testing and certification) which could be used to compare and assess the effectiveness of various technological approaches.

Another serious problem which should be discussed here for all the trace detection techniques is the clearing of vapors/particles of explosive material from the sample collection device, so that the next readings will be not influenced by any previous traces of explosive materials (memory effects that result in false positive alarms). Therefore, the equipment should give an alarm when a high level of contamination was reached.

3.2.2. Identification of explosive materials

There are currently a variety of commercially available chemical identification technologies that could be used to see if the sample collected previously contains any explosive materials.

It must emphasize here that the limits of detection of most techniques used in the aviation security field are generally sufficient to allow the identification of explosives in a sample. However, some technologies (such as mass spectrometry) that are able to identify and measure ultra-trace amounts of relevant chemicals (like explosives and illicit drugs) are too complex in utilization, because for instance they need highly trained operators to use the instrumentation and subsequently to maintain their high level of performance (detection capability) **[3]**.

The chemical identification/detection part of the trace detection system is smaller than the portal sample collection part of that system, so the sample collection system is determinant for the space and size needed in an airport.

Also, a series of trace chemical detection technologies are small enough to be incorporated into hand-held instruments, having the potential to use them in wand-type portable devices. The techniques under consideration here are:

- ion mobility spectrometry **[8]**
- mass spectrometry
- gas chromatography

- thermo-redox
- chemiluminescence.

The above mentioned technologies should be combined with a sample collection stage, because of the very low vapor pressure of explosives/drugs and their low concentrations. For instance, if the detection limits for IMS are on the low ppb range, by using preconcentration these limits were pushed toward low-ppt domain (3 ppt for TNT!) **[8]**. However, this need to collect a sample by moving very large amounts of air could be a drawback which may limit the application of these technologies as methods used in hand-wand devices.

One of the most promising and proven trace detection technique, which was implemented on a large number of airports, is Ion Mobility Spectrometry.

3.3. Nonimaging electromagnetic technologies

These technologies are used for continuous screening in various public places, such as clothing stores, sport stadiums, schools, libraries, court houses and so on. There are mature techniques, which function basically as metal detectors that detect thefts and for safety insurance. For airport security use, the improvements of nonimaging techniques should make them sensitive specifically to weapons. These systems are pre-programmed to recognize false alarms due to common nonthreat metallic objects (like belt buckles). Other improvements include making these metal detectors: more versatile in detecting a broad spectrum of metal alloys, more specific in locating the suspected threat items (like weapons) and more tolerant to any electrical noise generated by nearest sources (such as terminals, fluorescent lights, video displays).

The American civil aviation authority (FAA) is considering a nonimaging dielectric portal system which uses the microwave radiation and a pair transmitter/receiver to determine the complex dielectric constant of the objects that are screened, then the measured dielectric constant is compared to known responses for humans and threat objects. The levels of microwave power used for weapons' discovery are extremely low - less that 0.1% of the levels established for microwave energy safety regulations. A single 360° scan is completed in about 5 seconds.

The hand-wand electromagnetic screening devices are used for locating specific items and have already a widespread use in the airports. However, they are slower than portals. We have to underline an important disadvantage of the nonimaging electromagnetic screening techniques: these technologies are unfortunately unable to detect nonmetallic threat objects/materials. Microwave-based systems are capable to detect both metallic and non-metallic threat objects.

Compared with ionizing radiation, the possible health effects associated with non-ionizing fields (such as extremely low-frequency electric and magnetic fields) are even smaller **[9,10]**. Although some laboratory medical studies have confirmed that low levels of electromagnetic radiation may cause biochemical and physiological changes in human cells, they don't appear to damage the

DNA directly, and consequently they would be unlikely to initiate cancer. Also, these technologies are not expected to cause adverse effects on health of developing embryos and fetuses. A large number of epidemiological studies have already been conducted on reproductive and teratogenic effects (e.g., birth defects or spontaneous abortions) in human groups exposed to electromagnetic and magnetic fields from video display terminals (VDTs), power lines, and household appliances **[10]**; the results of these studies strongly suggest that the radiation and field exposures at the levels associated with passenger screening devices do not have reproductive or teratogenic effects. For instance, the exposure given by a VDT is a magnetic field of max. 2 milligauss (mG) at 30 cm from the screen, which is comparable to magnetic fields found near home television apparatus. A magnetic field strength of 2 mG will produce an electric field (at 16 kHz) of about 1 mV/m in the abdomen of the operator; for comparison, flying in an airplane through the magnetic field of the Earth produces a uniform static electric field of about 10 mV/m through the entire human body.

3.4. Clearing an alarm

The concept of "clearing an alarm" is related to the return of the instrument to its initial, pre-examination state.

As a matter of fact, only trace-detection technologies are expected to be affected by possible problems due to clearing an alarm (such as the memory effects). Neither imaging technologies, nor nonimaging electromagnetic technologies present a memory effect, which is a serious advantage.

In contrast to imaging technologies and nonimaging electromagnetic technologies, trace-detection equipments are interacting directly with the vapors/particulates of the materials of interest and indicate the presence of these substances if the concentration is above a threshold level. Ideally, the instrument signal should return automatically to its baseline (initial) value once the detection was completed; however, if the area close to sampling inlet is still contaminated or if the compounds of interest remain somewhere in the instrument then the equipment will be obviously unable to return automatically to its baseline level, and this is the phenomenon known as "memory effect". The contamination who generates memory effects will generate also persistent elevated signals without analyte in the sample, and may even trigger the alarm without a real cause (false positive alarms) **[3,8]**.

Contamination of the internal parts of the system may occur if:

- the vapors have high affinity for the materials which compose the sample collection part of the trace-detection instrument
- the particulate trace is dislodged from the subject screened by using mechanical means (e.g., air brushing), has high affinity for sample collection stage materials or remains stuck in the sample collection mechanism.

The memory effects could be minimized by a judicious choice of the materials used to build up the sample collection devices, so by using materials which do have a low free energy of adsorption for the molecules of explosives materials. As an additional feature, the instrument should have a mechanism for by-passing the sample collection inlet, just to verify (with uncontaminated air) the presence or absence of any memory effects.

Another serious issue refers to the tendency of most trace-detection systems to react to the presence of non-threating interferents (substances that are chemically similar to explosive materials, like some drugs used in medications). This would lead to false positive alarms.

3.5. Problems related to health and privacy

The health effects concerning trace-detection, imaging and nonimaging technologies used in the security screening systems were already discussed earlier.

At this point, however, it would be more than useful to present a summary of the basic problems associated with health and privacy. The conclusions that could be drawn are as follows:

- four categories of issues seem to be most relevant to public acceptance of passenger screening technologies: health, privacy, convenience, and comfort
- health concerns are more a risk perception problem, because in fact these technologies do not pose any significant health hazards; this problem could be effectively dealt with good communication and public education
- privacy concerns about displaying images of bodies and initiating physical contacts may be significant drawbacks to implementation of screening techniques
- convenience and comfort, in the form of avoiding time delays, appear to be also a highly important factor in public acceptance; technologies that require more than 6 seconds to screen each person are prone to be banned by the public.

4. Conclusions

Ensuring the security of the air travel system is definitely a monumental task, involving screening of millions of passengers (plus their baggage) every day for the presence of metallic weapons or dangerous materials. For this reason, the civil aviation authorities are looking for technologies that can address anticipated changes in security screening requirements, by expanding the ability to detect the presence of dangerous materials on a person. The increased probability of terrorist threats in the future will conduct to the higher acceptance and use of more invasive technologies.

Improvements to the current screening systems are of paramount importance; however, these improvements have to increase overall screening efficiency by simultaneously decreasing the number of false alarms and also by allowing the screening operators to solve more quickly these alarms by providing information about the specific type and location of the object that triggered the alarm. Although a series of screening technologies are already mature and ubiquitous, they could suffer further improvements to make them more effective for aviation security; for example, the metal detection portals can be improved by using parallel algorithms to detect simultaneously different metals, alloys, and structures, and detector arrays can be used to localize threat posing items much more specifically.

Technologies used and developed in the commercial aviation security screening can be broadly divided into imaging technologies or trace detection technologies, with their specific advantages and drawbacks. As for imaging technologies, in the current state of technology development human operators are required to interpret the images resulted, because they are familiar with various human and objects form and its variation. Trace-detection technologies, on the other hand, rely on the collection of samples (vapors and/or particles) of explosive materials to identify the presence of a threat; this collection can imply sampling the air around a person or touching the individual to remove the particles of explosive from the body, clothing or baggage. Of course, non-contact methods of sample collection (such as using an air shower or a vacuum device) are more acceptable to passengers' convenience, but they may be also less efective than contact sampling.

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