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Laboratory Evaluation of Two X-ray Baggage Inspection Systems

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LABORATORY EVALUATION OF TWO X-RAY BAGGAGE INSPECTION SYSTEMS

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ABSTRACT

The AS&E Micro-Dose Unit and the Mark VII Scanray Unit are two baggage inspection systems that have been developed for use in airline terminals that require high-volume detection of bombs, weapons, and other contraband. These systems were evaluated and the results are reported in terms of their operation, x-ray beam parameters, radiation levels, resolution parameters, and system cost.

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LABORATORY EVALUATION OF TWO X-RAY BAGGAGE INSPECTION SYSTEMS

American Science and Engineering (AS&E) X-ray Baggage Inspection System, Model 220

Introduction

The AS&E Micro-Dose X-ray Baggage Inspection System (Fig. 1) was designed for high-volume, detailed examination of packages at ultra-low x-ray exposure levels. This system is used in airline terminals for the detection of weapons, bombs, and other contraband. It is also employed by security personnel in other facilities to search packages for contraband carried in and out of secured areas. The Micro-Dose system has a unique design concept which includes an Automatic Threat Alert System (ATA) and a zoom display presentation feature.

System Description and Performance

The Micro-Dose system consists of four subassemblies (Fig. 1): the electronic display console, the detector (behind the console), the conveyor, and the x-ray source cabinet. The Micro-Dose design concept differs from the conventional pulse x-ray beam system that uses a fluorescent TV camera system. With the conventional method, information is recorded simultaneously from the entire object. The Micro-Dose system records information sequentially by using a rapidly moving, 1-mm^2 x-ray beam (Fig. 2). The beam scans the object and strikes the detector located on the opposite side of the conveyor.

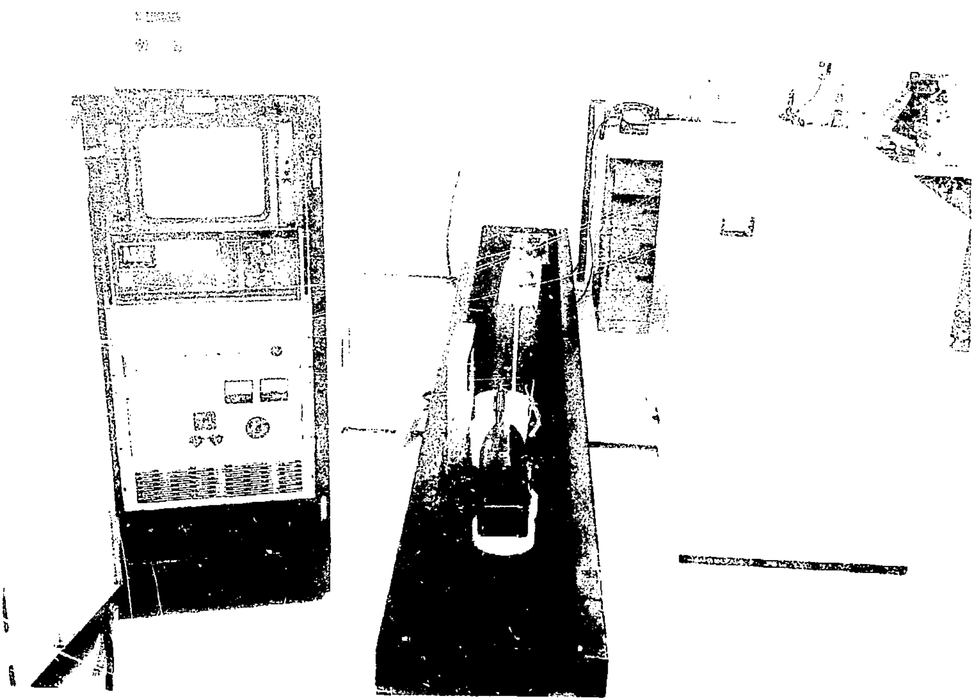

Figure 1. AS&E Micro-Dose X-ray Baggage Inspection Unit

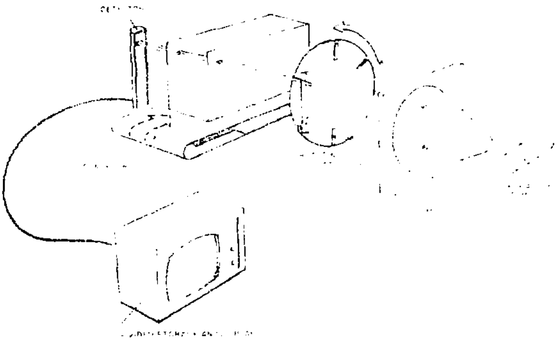

Figure 2. Principle of operation of [illegible]

The detector is a [illegible]-long sodium [illegible] coupled to a photomultiplier tube (PMT). [illegible] to pulses of light that produce corresponding electri[illegible] PMT output. The more dense and [illegible] attenuate the x-ray beam and reduce the PMT [illegible] sweeping x-ray beam generates [illegible] package and contents. [illegible] the package on the conveyor results in two[illegible] information. A video/graphic [illegible] one-line images as they are produced [illegible] tion. Each one-line image [illegible] on a TV monitor as a complete, two-dimens[illegible] density appear darker on the TV monitor [illegible] image of a heavily packed tool case [illegible] right-hand corner and [illegible] corner. This image was made at the faster conveyor [illegible] 1[illegible] cm/s. The image [illegible] located at a distance from the dete[illegible] elongated at the slower conveyor speed [illegible] The [illegible] in more scans per inch [illegible] quality images.

[illegible] additi[illegible] to the
audio and visual
[illegible] as a preset
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of the TV monitor
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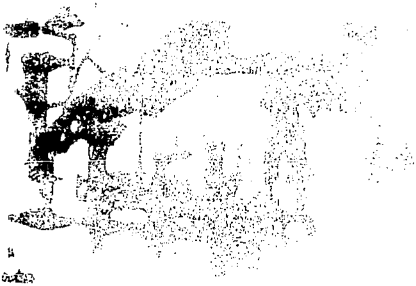
the isolated items



[illegible]

efficiency [illegible]

nearly the [illegible]

examination [illegible]

caused by scattered radiation. The scattered background radiation is essentially eliminated by the narrow entrance slit, the size of the x-ray beam, placed along the length of the detector. Table I shows the manufacturer's system specifications from the AS&E brochure for Model 222. Model 220, used at Sandia Laboratories, is a similar model of reduced physical size.

System Operation

The system is controlled by a onrole unit which has the following basic functions: Electrical power on, control warm-up time, x-ray tube voltage selection, conveyor mode, conveyor direction of movement, and conveyor start. Various timing and logic circuits control the system operation. When a package is placed on the moving conveyor, it interrupts a photocell beam which initiates the inspection and data-gathering process. The inspection area is surveyed for about 8 s before the total image is displayed.

Delivery time for the Micro-Dose Model 220 system to the laboratory was approximately 30 days. The unit was installed by the manufacturers and was in operation in about 5 h.

TABLE I

Performance Specifications, Micro-Dose Model 222

Maximum Overall Dimensions:

Height	77 in. (196 cm)
Length	120 in. (305 cm)
Width	53 in. (135 cm)

System Weight:

~2000 lb (900 kg) packaged for shipment

Maximum Parcel/Baggage Size (Main Conveyor):

Height	28 in. (71 cm) (56" [142 cm] with a second inspection)
Length	37 in. (94 cm) (unlimited in RUN INTERMITTENT Mode)
Thickness	36 in. (91 cm)
Weight	300 lb (135 kg)

Maximum Parcel/Baggage Size (Small Conveyor):

Height	9 in. (22 cm) (18 in. [46 cm] with a second inspection)
Length	222: 14 in. (36 cm) (unlimited in RUN INTERMITTENT Mode)
	222E: 12 in. (30 cm)
Weight	45 lb (20 kg)

Conveyor Belt Speed:

Main conveyor	4.6 in. (12 cm)/second (nominal)	
Small conveyor	222:	1.8" (5 cm)/s (nominal)
	222E:	1.4" (4 cm)/s (nominal)

Minimum Detectable Wire:

Main conveyor	at least 24 Awg (0.020 in./0.5 mm diam) copper wire
Small conveyor	at least 26 Awg (0.016 in./0.4 mm diam) copper wire

Grey Scale:

At least 10 distinguishable steps, log-related scale

Radiation Exposure:

To parcel	0.005 mR/inspection (over 200 inspections before film fog)
To operator	0.1 mR/h (~1/5 of US Federal Standard for cabinet X-ray systems)

Peak Voltage of X-Ray Power Source:

100 kV

Display Mode:

Standard 16 in. (41 cm) TV monitor

Operating Environment:

Electrical power	222:	120 Vac 60 ± 0.5 Hz, 2.75 kVA single phase
	222E:	220 Vac 50 ± 0.5 Hz 2.75 kVA single phase
Ambient temperature		50°F (10°C) to 90°F (32°C)
Relative humidity		20% to 90% (noncondensing)

System Parameters

X-Ray Beam

The Micro-Dose high-voltage power supply (HVPS) produces a dc voltage of 50, 75, or 100 kilovolts peak (kVp) for the x-ray tube. A voltage divider network provides for measurement of the tube voltage. HVPS measurements were taken with the tube disconnected. These no-load voltages were 3 to 5% higher than indicated at the HV switch positions.

A laboratory scintillator/PMT detector was used with a multichannel analyzer for spectral measurements of the x-ray beam. An aluminum filter reduced the beam intensity to a level that insured accurate photon count results. For operational current loads (5-10 mA), the maximum photon energy (keV) that was observed corresponded closely to the voltage set at the switch. For 100 kVp and 0.5-mA tube current, the maximum photon energy closely conformed to the no-load HVPS measurements of ~103 kVp.

The half-value layer (HVL) method was used to determine the effective energy of the x-ray beam (keV_{eff}). The HVL is the thickness of material required to reduce the beam intensity to one-half the original intensity (I_o):

$$1/2 = e^{-\mu(HVL)} \text{ and } (HVL) = 0.6/\mu.$$

μ is the absorption coefficient for a given material. The effective beam energy is determined by measuring HVL, solving for μ, and finding the corresponding beam energy from published values of μ vs beam energy for aluminum.

An HVL measurement using thin copper sheets, a 0.5-mA tube current, and a Rad Owl ion-chamber monitor located 56 cm from the source yielded values of 0.375 mm for HVL and 55.7 for keV_{eff}. A value of 52 keV_{eff} was found using thin 2024 aluminum sheets and correcting for the presence of alloy materials.

Radiation Level

The radiation exposure to a parcel, as specified in Table I, is 0.005 mR/inspection. An exposure measurement in the laboratory, with the Rad Owl monitor located 132 cm from the source (the approximate location of a scanned package), indicated an exposure of 0.003 mR/inspection.

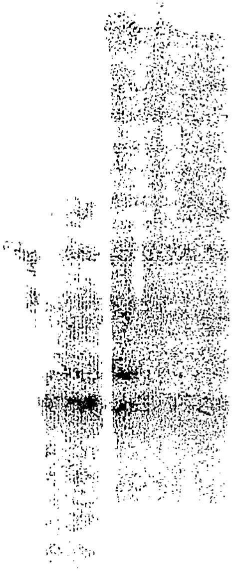
Scattered Radiation

Sandia Health Physics Division personnel made leakage radiation surveys with a Rad Owl monitor on the surface of the operating unit. Leakage radiation was undetectable over a period of about 15 min of intermittent operation. Table I specifies 0.1 mR/h exposure to an operator ($\sim$1/5 of Federal standards). Later AS&E data specifies $<$0.01 mR/h and $<$0.01 μR/inspection exposure to an operator.

Resolution

Spatial resolution and contrast resolution are demonstrated in Figures 5 and 6. Figure 5 was taken at fast conveyor speed and Figure 6 at slow conveyor speed. Wire samples for spatial-contrast determinations are labeled with lead numbers according to Awg wire diameter. The #26 wire is easily distinguished at the TV monitor although contrast is lost in reproduction of the photographs. The resolution elements were positioned midway between the x-ray source cabinet and the detector cabinet, which are approximately 119 cm apart.

Speed



Figures 7 and 8 show two examples of video-waveform scans across the resolution wires at both conveyor speeds. At fast speed (Fig. 7), the approximate peak-signal to rms-noise ratios (S/N) are as follows: 26 for #8 wire, 10 for #20 wire, and 3 for #26 wire. At slow speed (Fig. 8), the S/N values are approximately 31, 16, and 6, respectively. These results were obtained with the object on the conveyor at about maximum distance from the x-ray cabinet (93 cm). This is the maximum variation observed in values of S/N. At distances of 54 cm and 15 cm, and on other scan lines, values of S/N also varied but tended more towards the higher values.

An aluminum step-wedge was included in Figures 5 and 6 to assess the system contrast (grey levels). This wedge was previously designed for approximately 50 keV_{eff}, i.e., the second step corresponds to the HVL. A square, opaque, lead-sheet reference is clearly silhouetted against the last grey level. This indicates that the system contrast was greater than nine grey levels, and is estimated to be at least ten. Figure 9 shows a video waveform scan across the step wedge with the wedge at 54 cm from the x-ray cabinet. This scan is at the slow speed to accentuate the grey levels. The lowest step (on the left) is the result of the lead sheet reference. The relatively large signal reduction indicates a larger dynamic range than measured--at least 10 grey levels.

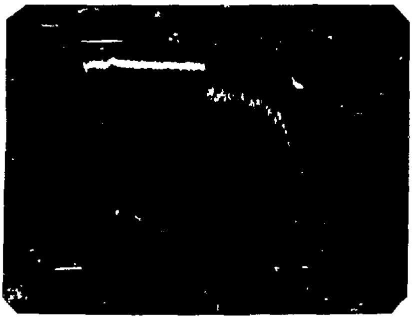


Figure 7. Wire Samples, Fast Speed (93 cm from x-ray cabinet)

Figure 8. Wire Samples, Slow Speed (93 cm from x-ray cabinet)

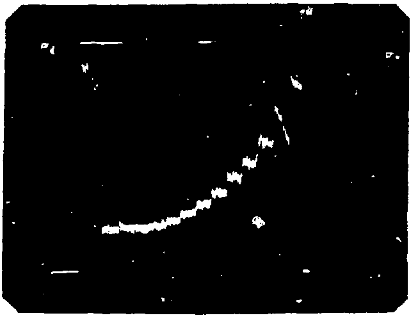
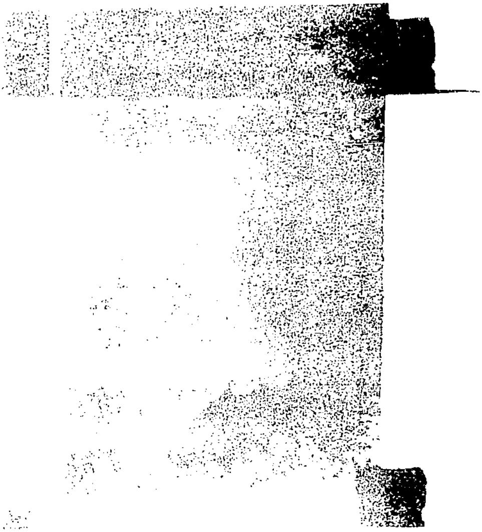


Figure 9. Wedge Samples, Slow Speed (54 cm from x-ray cabinet)

Cost

At the time of purchase, the Micro-Dose 220 unit cost $54,000. The ATA feature cost an additional $4,000.

is its ability to
with the contrast-
for maximum density
. a revolver was
minum alloy plate.
image of the revolver



m Aluminum Block

shield is exceeded, but
this, th n,

constitutes a [illegible] requirement to [illegible] an alarm. A[illegible] smaller than the [illegible] are integrated over the entire [illegible] an alarm is activated when the total area [illegible] exceeds the [illegible]. Therefore, it is possible to detect an item [illegible] it is disassembled, distributed within the [illegible] [illegible] size.

Conclusion

[illegible] AS&E Micro[illegible] X-Ray [illegible] inspection [illegible] engineered and well-manufactured unit. [illegible] quality images for [illegible] best possible recognition [illegible] performance. The system's ATA unit, with [illegible] functions as both a detection aid [illegible] toward automated operation. The Micro-Dose [illegible] available for immediate installation in [illegible] inspection.

Mark VII Scanray X-ray Baggage Inspection System
Model 01-0472-100

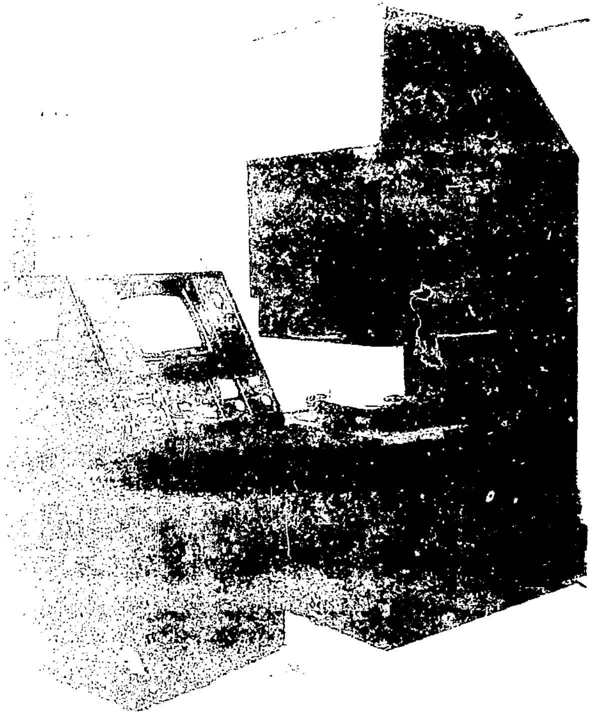
Introduction

The Mark VII Scanray X-Ray Baggage Inspection System (Fig. 11) is the type commonly found in airline terminals. It can be employed by security personnel of other facilities to search packages for contraband carried in and out of secured areas. A manually-operated Mark VII unit was procured because a conveyor model was not required for laboratory evaluation.

System Description and Performance

The Scanray Mark VII Inspection System is a pulsed x-ray beam, fluoroscopic, TV camera system. A single 60-Hz, half-wave, 1/120 s, high-voltage pulse is applied to a medical type x-ray tube to generate the beam. The beam from the tube, at the top of the unit, excites a large fluoroscopic x-ray screen mounted below the floor of the package inspection area. The item to be examined is positioned in the area between the screen and the x-ray source. The x-rays penetrate the item and those which are not totally absorbed excite the fluorescent screen. The fluorescent screen converts the invisible x-ray image into a visible image of various shades of brightness. All materials absorb x-radiation in varying degrees, depending upon the absorption coefficient and the thickness of the material. The more absorptive objects appear darker on the fluorescent screen.

The resultant image on the screen is transmitted through an electro-optical system, which contains a number of image-intensifier stages that are capable of amplifying light, to produce a usable image on a vidicon tube. A disc-storage memory unit, included in the television chain, provides a stored image. A closed-circuit television monitor, mounted in the control/display console, presents the stored image to the operator.



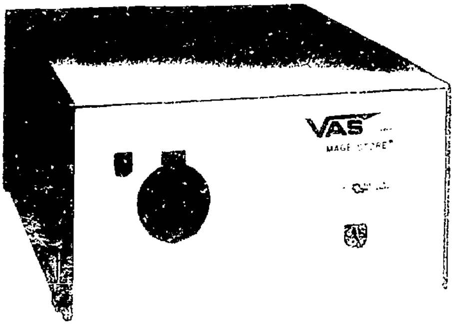


IMAGE [illegible]

TABLE II

Performance Specifications
Scanray Model 01-472-100
Pulsed X-ray with Video Image Storage

<u>SYSTEM</u>	
Resolution	26 gauge solid copper wire
Leakage (5 cm from all external surfaces)	Meets requirements of Federal Specification 21-CFR-1020. 40 (Leakage low as practicable-0.45 mR/h in worst care)
Average dose/inspection	0.18 mR (single pulse) at 4 ft
Shades of gray	10
Power requirement	110 V, 60 Hz. 600 W max
Safety	Certified to meet the BRH requirements for safety Federal Standard 21-CFR-1020.
	40 for Cabinet X-ray systems.
<u>X-RAY HEAD</u>	
Peak voltage	Continuously variable, 65 kV to 125 kV
Tube Current	Variable - Typically 10 mA
Filtering	2.5 mm Al (inherent) + 5.5 mm Al (optional)
Duty Cycle	100%
Cooling	Sealed oil bath (no external cooling required)
Beam divergence	40°
Beam orientation	Vertical downward
Pulse duration	1/120 s
<u>VIDEO SYSTEM</u>	
Specifications for 1-in. vidicon (16 mm diagonal, 4:3 format):	
<u>Objective Lens</u>	25 mm/f0.95 or 16 mm/f1.4
<u>Image Intensifier</u> (2-stage)	
Gain	8×10^3
Resolution	35 line pairs/mm
Noise	2×10^{-11} L/cm^2
<u>TV Camera</u>	
Resolution	450 TV lines (horizontal)
Shades of grey	10
Horizontal frequency	15.75 kHz random interlace
Vertical frequency	60 Hz, line-locked
<u>Storage System</u>	
Method	100 - Track disc, field recording
Resolution	340 TV lines (70% modulation)
<u>TV Monitor</u>	
Resolution	over 600 TV lines (horizontal)
Linearity	less than 2% distortion

TABLE III

Physical Specifications
Scanray Model 01-0472-100

X-RAY INSPECTION UNIT	
Weight	900 lb
Length	44 in.
Width	30 in.
Height	90 in.
Construction	Steel base on casters. Steel frame cabinets covered with enamel finish steel panels.
MOBILE CONTROL CONSOLE	
Weight	250 lb
Length	27-1/4 in.
Width	28 in.
Height	54 in.
Construction	Steel base on casters. Steel frame cabinets covered with enamel finish steel panels.

System Operation

Operational difficulties of the system during factory production resulted in a delivery delay of approximately 4 months. After delivery, approximately 6 weeks were required to modify the unit so that it would operate within its procurement specifications. The difficulties included electronic control system malfunctioning and 125-kVp, single pulse, x-ray beam generation problems as well as excessive TV image flickering and image tearing. The factory personnel determined, after considerable experimentation, that these effects were caused by the use of a "frame" disc-storage unit with a 1/120 s, single pulse, x-ray beam. In a frame unit, two alternate horizontal field scans are recorded in series, and these displays are then interlaced. The later field scan is lower in intensity because of the relatively short beam duration and the relatively fast decay time of the fluorescent screen. Therefore, when the two fields are alternately displayed, the entire monitor screen flickers between the lighter and darker images at the visible display rate. The flicker was eliminated by using a field storage unit which records only one-half of the horizontal scan lines with no interlaced display. However, resolution was reduced by a factor of two. A better solution would be to use a series of at least two, 1/120-s, x-ray pulses to provide sufficiently long beam duration and screen activation.

Once properly installed and adjusted, the unit was intermittently operated in the laboratory for a period of several months. It is estimated that 1500 exposures were made during this time.

System Parameters

X-Ray Beam

A direct measurement of the x-ray tube peak-voltage (kVp = 125 kV max) was not obtained because the HV transformer and tube are both contained in an oil-filled, sealed enclosure with no convenient access. Therefore, the following indirect methods were employed to make this measurement (methods 1 and 2 duplicate the manufacturer's methods):

1. The effective beam energy (keV_{eff}) was determined by measuring the HVL with a Rad Owl Model RO-1 ion-chamber monitor and thin 2024 aluminum sheets. The HVL measured 4.75 mm. (The inherent filtration of the medical x-ray tube was 2.5 mm of aluminum. A conical aluminum filter of approximately 2.5-mm average thickness was also present to produce a more uniform radiation field.) Solving for μ, correcting for the 2024 alloy, and finding the corresponding x-ray energy from published values of μ for various values of x-ray energy, gave a beam energy value of 49 keV_{eff}. The beam energy value was 33 keV_{eff} with the conical aluminum filter removed. Multiplying the effective energy by a factor of two indicated a peak tube-voltage

of 98 kVp. This factor was used for sine-like voltage waveforms. The somewhat low effective-beam-energy measurement may be the result of low-energy radiation from the uncollimated x-ray beam preferentially scattered within the inspection area or, possibly, a distorted voltage waveform at the x-ray tube. The HV transformer secondary was not accessible, so voltage and current observations were made at the transformer primary input. Figures 13 through 18 show variations in pulse shape with input level. This implies a nonsinusoidal waveform at the x-ray tube.

2. A graph of exposure vs distance for various tube voltages, for the Model 1890 x-ray tube with no additional filtering, appears in the "Radiological Health Handbook," HEW, 1970. Data from this graph indicates a tube voltage of approximately 125 kVp for a measured dose rate of 22 mR/mA-s at 81 cm. Dose-rate measurements, without the conical filter, were integrated over 15 exposures at 10 mA average tube current.

3. A multichannel analyzer and NaI scintillator/PMT detector were used at Sandia for spectral observations of the x-ray beam. The spectral data, at 8 mA tube current, extended to approximately 125 keV, which indicates that the maximum tube voltage was approximately 125 kVp.

Figure 13. Scanray X-ray Voltage and Current at 8 mA, 75 kVp

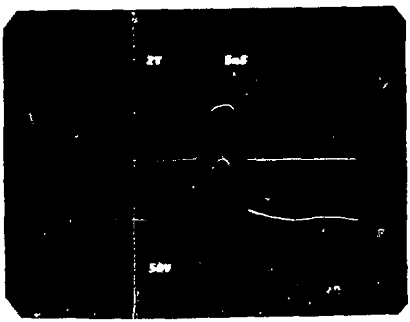


Figure 14. Scanray X-ray Voltage and Current at 13 mA, 75 kVp

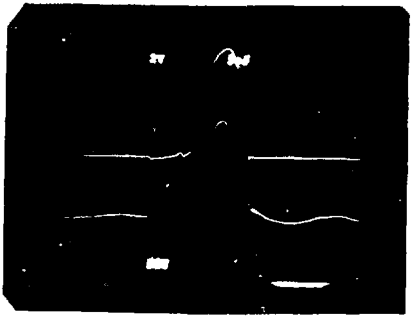


Figure 15. Scanray X-ray Voltage and Current at 25 mA, 125 kVp

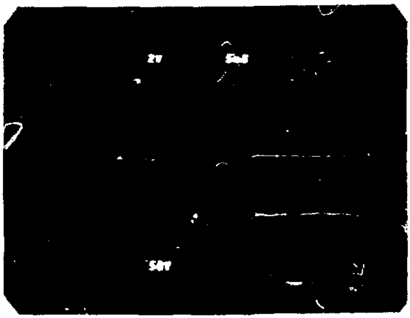


Figure 16. Scanray X-ray Voltage and Current at 25 mA, 75 kVp

Figure 17. Scanray X-ray Voltage and Current at 8 mA, 125 kVp

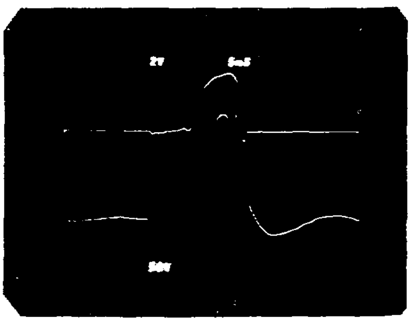


Figure 18. Scanray X-ray Voltage and Current at 13 mA, 125 kVp

Radiation Level

The average single-exposure dose to a package in the baggage area was 0.27 mR/inspection with the conical filter in place. The measurement was made with the Rad Owl monitor at 81 cm and the tube power at 125 kVp/8 mA. The dose was 1.8 mR/inspection without the filter. This corresponds to 0.12 mR/inspection with the filter and 0.79 mR/inspection without the filter at a monitor distance of 122 cm. The specifications show 0.18 mR average dose/inspection at 122 cm with filter.

Scattered Radiation

Sandia Health Physics Division personnel made leakage radiation measurements at the surface of the unit. Rad Owl monitors were used in the integrating mode and the system was pulsed at about 1 pulse/3 s. The maximum dose at any location did not exceed a rate of 0.20 mR/h, which confirms the manufacturer's measurements and meets the specified requirements of the Bureau of Radiological Health (BRH).

Radiation Field Uniformity

Figures 19 through 22 are oscilloscope photographs of single TV monitor scans showing the intensity variation across the top, center, and bottom of the field of view, with and without the conical filter. The improvement in uniformity with the filter is evidenced by the more constant amplitude of the scan in Figures 21 and 22. This was verified by the measurements of the dose rate as a functioo of position in the inspection area. The field nonuniformity without the filter produces a central hot spot in the TV monitor images in Figures 23 and 24.

Resolution

Photographs of the TV monitor displays of various objects are shown in Figures 23 and 24. The conical filter was not used in these figures, and it was found that operation without the conical filter produced better results in terms of display intensity, contrast, spatial resolution, and beam-power range. Therefore, the filter was not used in all subsequent operations.

Figure 19. Scanray, No Object, Center Line, No Filter--8 mA, 125 kVp

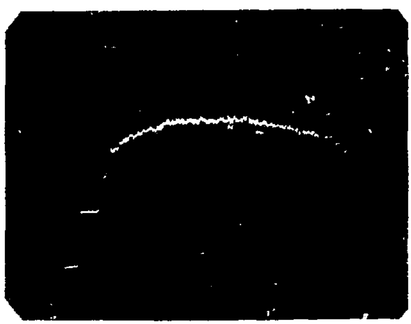


Figure 20. Scanray, No Object, Top Line, No Filter--8 mA, 125 kVp

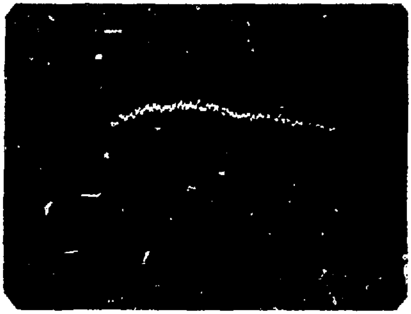


Figure 21. Scanray, No Object, Center Line, with Filter--8 mA, 125 kVp

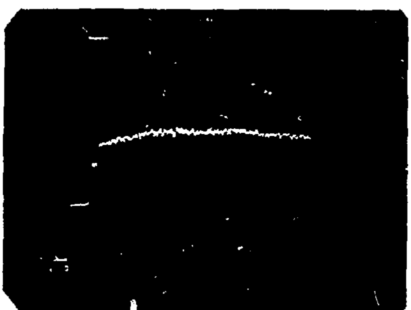


Figure 22. Scanray, No Object, Bottom Line, with Filter--8 mA, 125 kVp

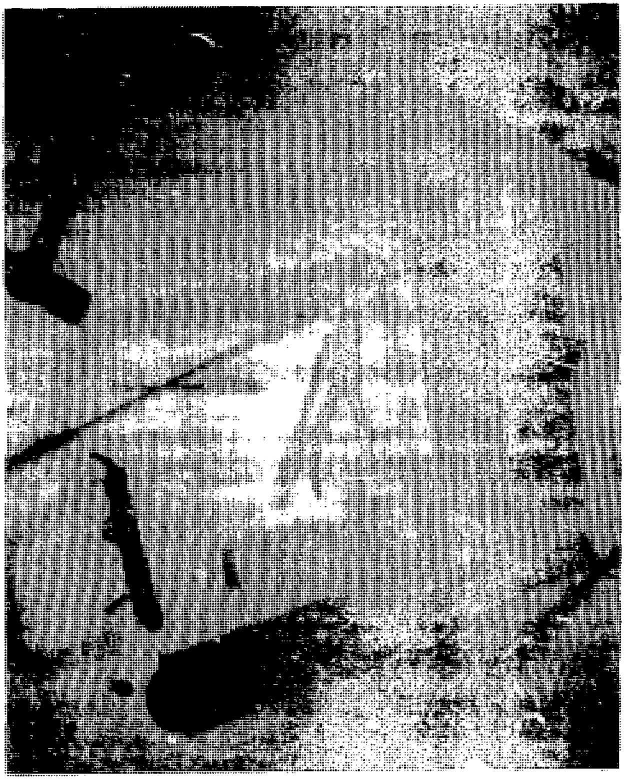


Figure 23. TV Monitor Display [illegible]

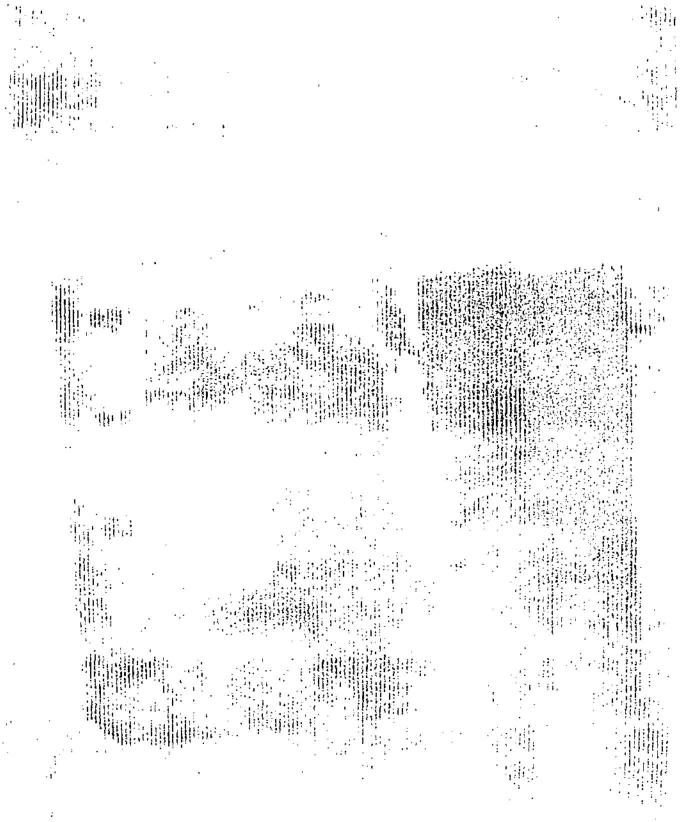


Figure 2[illegible]. TV Monitor Display--Contents of Lunch Box

The objects in Figure 23 include various tools, a leather briefcase containing a spray can, a bottle containing wax, and twisted #28 wire. The circular object at the top right is the conical filter. At top center are four groups of three, curved, insulated wires that are used to determine resolutions. The wire sizes of each group are labeled with lead numbers. The #26 wires are visible, as specified, at the very top of the photograph. Figure 24 shows a lunch box containing a thermos, a fork, a plastic cup, and a pear. The four groups of wires are located at the lower left side of the photograph. The twisted wires are directly above the lunch box. These photographs show the single-field monitor display, which consists of one-half the number of scan lines in a full-frame display.

TV video-waveform scans across the resolution wires are depicted in Figures 25 and 26. The wire signals are low amplitude, short pulses slightly at the background trace. The peak-signal to rms-noise ratio is approximately 9. The data processing capability of the human eye and brain contributes to image recognition with signals of relatively low S/N ratios.

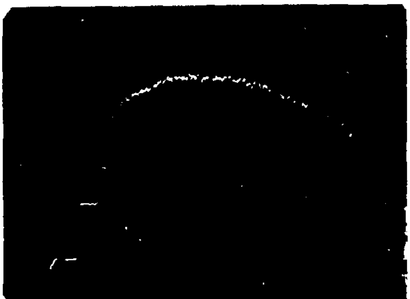


Figure 25. Scanray of Wires (right half of screen) Taken Without Filter

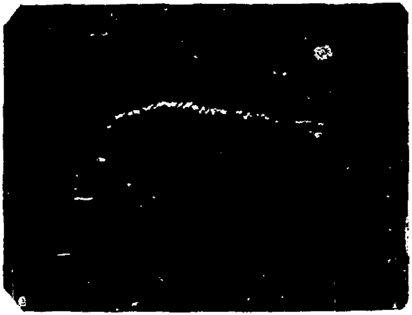


Figure 26. Scanray of Wires Taken with Filter

Two aluminum step-wedges appear on the right sides of Figures 23 and 24. The darker wedge demonstrates nine levels of contrast resolution. The second step of the wedge is equal to the HVL. (The other wedge was designed for lower energy beams.) A maximum of seven grey levels are visible in this exposure. Two lead sheet triangles, opaque to the x-ray beam, were placed over the thick end of the wedge as a reference. Figures 27 and 28 show a video-waveform scan across the step-wedges which demonstrates the difficulty of distinguishing grey levels beyond the 6th or 7th level. This result is consistent with a S/N ratio of approximately 9. Data from Figure 20 indicate a S/N ratio of approximately 11.

Figure 27. Scanray, 30 keV Step Wedge, No Filter

Figure 28. Scanray, 60 keV Step Wedge, No Filter

Conclusions

The Mark VII Scanray Baggage Inspection System meets the essential FAA airline requirements for visual detection of concealed objects by an operator. This unit also meets BRH Radiation Safety Requirements and is filmsafe for one exposure. The present single-pulse system could be improved by using multiple pulses to obtain a full-frame display capability and better image resolution.

Summary

The AS&E Micro-Dose System uses a flying spot scanner, with a 1-mm^2 x-ray beam cross-section, and a scintillator/PMT detector to display an image on a standard TV monitor. The x-ray tube potential can be set at levels of 50, 75, and 100 kVp/8-10 mA. Number 26 Awg wire is resolved at fast conveyor speeds, and #30 wire at slow speeds. The video S/N ratio is approximately 30. The grey-level contrast is approximately 10 levels. Radiation exposure to a package is filmsafe at 0.003 mR/inspection. Exposure to an operator per inspection was unmeasurable with the Rad Owl monitor during an 15-min period observed by Sandia Health Physics personnel. A unique feature of this system is the ATA, which enables an operator to detect more easily objects partially obscured by clutter.

In the Mark VII Scanray system, complete images are obtained with a single x-ray beam pulse. A fluorescent screen converts invisible x-ray images to visible images of varying intensities. This image is viewed by an image intensifier and TV camera and is displayed on a standard TV monitor. Number 26 Awg wire is resolved. The grey-level contrast is approximately 7. Radiation exposure to a package is filmsafe with and without filtration. Radiation leakage does not exceed 0.20 mR/h at any location on the surface of the unit. The x-ray tube potential is variable from 65 to 125 kVp/8 mA, with a single-pulse beam mode of 1/120 s duration. The S/N ratio is approximately 9.

A listing of the characteristics of both systems is presented in Table IV.

TABLE IV

Unit Characteristics of the AS&E Micro-Dose and Mark VII Scanray Systems

	American Science and Engineering Micro-Dose	Astrophysics MK VII (Model 01-0472-100)
Maximum Package Size	71 x 94 x 91 cm	81 x 61 x 36 cm
Conveyor	Intermittent/reversal 9-20 ft/min	None
Throughput	1200 packages/h	250/h
Automatic Threat Alert	Yes	No
Display	Standard TV monitor 525 TV lines	Standard TV monitor Single-field storage ~260 TV lines
Imaging Method	Flying-spot scanner, Scintillator-PMT detector Scan converter with 20-min memory	Fluorescent screen Image intensifier TV camera--video Disc Recorder
S/N Electronic Ratio	~30	~9
Resolution	26-Awg wire 30-Awg wire on slow speed	26-Awg wire
Contrast (Grey-Scale)	~10 levels	~7 levels
Radiation Exposure Per Inspection To Package/To Operator	0.003 mR/<0.01 μR Meets BRH standards Filmsafe	0.79 mR/0.05 μR Meets BRH standards Filmsafe with and without filtration
X-Ray Tube Potential	50-75-100 kVp/8-10 mA 3 steps	65-125 kVp/8-10 mA variable
Beam Mode	Chopped-CW 1-mm^2 area	Single pulse 1/120-s duration
Cost (1977)	$54,000 basic unit $58,000 with ATA	$39,000 with 100 Channel disc-storage unit