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PROTECTION OF PUBLIC FIGURES

SYMPOSIUM PROCEEDINGS

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U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER

FORT BELVIOR, VIRGINIA

403160

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WELCOME

By: COL Bennett L. Lewis, Commanding Officer, USAMERDC

Welcome to MERDC. Anyone who has been alive during the past twenty-four hours and has been listening to radio or television or reading the newspapers (attempted assassination of Governor Wallace) knows that this symposium on Protection of Key Public Figures needs no further introduction.

I want to introduce this symposium by describing our organization and why the Mobility Equipment Research and Development Center is the sponsor of this symposium. First, a brief review of our organizational chain of command. Our next higher headquarters is the Mobility Equipment Command, commanded by Major General John C. Raaen, Jr., and the next higher headquarters is the Army Materiel Command, commanded by General Henry A. Miley, Jr. AMC is one of three major commands in the Department of Army and is the provisioner of materiel to meet the Army's needs. Of the other two commands, the Combat Developments Command (CDC) determines what the Army needs in terms of materiel and troops; AMC provides the materiel and the U.S. Continental Army Command (CONARC) provides the troops.

For managing the materiel it provides, AMC is subdivided into seven major subordinate commodity commands. You should be able to recognize the commodities for which each of these subordinate commands is responsible by the title of the command, with one exception--the Mobility Equipment Command. You might consider MECOM the 1972 version of the purveyor of the nail of the shoe of the horse. We in MECOM work on systems, materiel, and procedures to make certain that the mobility potential of the tanks, aircraft, vehicles, and equipment of the other commands is in fact realized on the battlefield or in support of the combat troops. The fields of endeavor for which MECOM and MERDC are responsible are mine detection and mine neutralization and detectors and sensors. These fields provide the technical expertise that led to the assignment of the project on protection of key public figures. Of all of the work done within the Army on sensors for Vietnam, more than half was accomplished here at MERDC with the assistance of contractors.

Within MERDC's organization work with the broad range of disciplines associated with the fields of endeavor is accomplished within the four major operating departments. These departments include Electrotechnology, Military Technology, Mechanical Technology, and Countermine/Counter Intrusion. The sponsor of this symposium is the Countermine/Counter Intrusion (CM/CI) Department. It was established about a year ago in response to the increase in emphasis on countermine efforts engendered by the casualty reports to military vehicles as well as personnel from Vietnam. The CM/CI Department absorbed the then existing Intrusion Detection and Sensor Laboratory which worked on projects assigned by the Defense Communications Planning Group, now known as the Defense Special Projects Group.

The support echelon of MERDC provides support not only to these four departments but to tenant laboratories which occupy facilities on the Center's grounds. These include the Night Vision Laboratory, the Engineer Power Group, the Engineer Topographic Laboratories, and others.

As with any U.S. Army organization, our most important asset is people. MERDC is one of the laboratories designated to participate in Project REFLEX. Under this project, MERDC has no manpower ceiling, but rather the work force is determined by the value and content of the approved programs. Currently, MERDC requires a workforce of 1300, which is to include approximately 500 scientists and engineers.

MERDC's work is not only within R&D programs and supported by R&D funds, but our programs include work in the PEMA (Procurement of Equipment and Missiles, Army); that is, investment money to buy hardware. OMA (Operation and Maintenance), and customer funds. The PEMA funds are in support of quantity production contracts and the OMA funds are in support of procurement of small, secondary items where the major effort is the preparation of specifications. Customer funds may be in any of the other accounts--R&D, PEMA, or OMA. In FY 70 the total obligation authority of MECOM was approximately $117 million, about half being customer funds. In FY 71 the total obligation authority was approximately $77 million, with about $30 million of that total a carry-over from preceding years. In FY 72 we are currently at $83 million and expect to have programs totaling $100 million. Under Project REFLEX one might have expected our MERDC workforce to grow in FY 72, but it has not.

Facilities available to MERDC include a test area of 820 acres on the west side of Shirley Highway, a part of the Fort Belvoir complex. A major portion of this area is used for testing of detectors and sensors.

In closing, the challenge that faces the attendees at this symposium is great. I note from the rosters that each of you belongs to an organization with a major responsibility in securing the safety of our citizens and dedicated to meeting that responsibility. I hope that this symposium contributes to a solution to the problem facing us and also hope MERDC is a good host in the sense that we educate and stimulate you, and that we provide for your comforts. Thank you for your attention and your attendance.

PROBLEM OVERVIEW

By: Joseph E. Boneta, Chief, Intrusion Detection Division, Countermine/Counter Intrusion Department, USAMERDC

Colonel Lewis has gone into the background of who we are and into our R&D efforts. We have been involved in the area of the protection of public figures for about three years, and we look upon our efforts as fitting into two broad scenarios. In the first scenario we have access control. That is, we can channel the subject through a doorway, a hallway, a portal, a fence, and thus subject him to covert surveillance for weapons or explosives concealed on his person. This is relatively easy to do compared to the second scenario, which is crowd surveillance for the same purpose. A typical example is the circumstances of the assassination attempt on Governor Wallace in Laurel, Maryland, yesterday. This was a crowd scenario. The question is, "How do you protect public figures against the sort of thing that happened there?" We have a crowd situation here today and we might want to know, in similar situations, who has weapons or concealed explosives on his person. So insofar as MERDC is concerned, the two broad scenarios that we will be talking about are those in which we have access control and those in which we do not.

Now, it is obvious from your presence here that there are many Federal, State, and Municipal agencies interested in the same or related activities. We therefore thought that it was high time we all got together to discuss our mutual problem areas. I would like to give you a quick feeling of the mix of people here today--from DoD: Army, Navy, Air Force, National Security Agency, and Defense Special Projects Group; from Federal non-military agencies: Customs, Postal, FAA, Department of Transportation, Secret Service, CIA, Atomic Energy Commission, Government Services Administration, National Capitol Police, and the National Bureau of Standards. State police are present from Virginia, Maryland, Indiana, North Carolina, Alabama, and Connecticut. Municipal police are present from Metropolitan District of Columbia, Miami, Dallas, Philadelphia, New York City, and San Jose. In addition, we welcome representatives from Great Britain, Canada, and Australia. So we have a tremendous mix of people who all have the same goals and who may be engaged in related efforts.

We would like to point out that there will be discussion panels on dogs, magnetic detectors, X-rays, and human behavior. I would like to suggest that you hold your questions and comments for the panel discussions. However, if you have questions that you want to ask the speaker--just fire away. We want the symposium to be very fruitful for all attendees and will make time adjustments as required. To kick off our symposium we have a representative from the Army Materiel Command's RD&E Directorate, Mr. Victor Suski. I think if he had picked his timing and prepared his presentation this morning, it could not have been more timely, because he is going to talk to us about "A Fundamental Look at Assassination and Political Violence."

AND HAVING WRIT MOVES ON
(A Fundamental Look At Assassination And Political Violence)

By: Victor Suski, U.S. Army Materiel Command

The Moving finger writes; and, having writ,
Moves on: nor all your Piety nor Wit,
Shall Lure it Back to Cancel half a Line,
Nor all your tears wash out a Word of it.

from the Rubaiyat
Omar Khayyam

Thirty-one years ago Pitirim Sorokin, then Chairman of the Department of Sociology at Harvard University, published a book, "The Crisis of our Age," in which he examined our culture and society and explained where he thought we were headed. I first read this book some 15 years ago and was impressed then by Sorokin's passion and the avalanche of historical facts he used to support his thesis. I never forgot Sorokin's book. It resided quietly in my memory, kept alive by the all too-often occurrences of bombings, hijackings, riots, and what appeared to be the collapse of our moral values and the flight of reason and common sense from the public discourse. I asked myself, "What is happening to us? What does this all mean?" So, nudged by that quiet memory, I went back to Sorokin. As far as I am concerned, he presents the only logical and detailed answers to the questions of what is happening, why it is happening, and where are we going. His diagnosis fits the facts. If you believe Sorokin's diagnosis, then you'll understand why this symposium and the devices and techniques to be demonstrated here are necessary and, in a unique way, vital. You will see that we really have no choice but to treat the symptoms, such as assassinations, (and treat them we must) until the disease runs its course.

What then is Sorokin's thesis? Let us begin. Any great culture represents a unity whose parts--philosophy, religion, ethics, law, art, science, mores, manners, economics, etc.--are permeated by the same fundamental principle and in turn articulate the same basic value. The parts of such an integrated culture are also casually interdependent. If one important part changes, the rest of its important parts are bound to change. (Culture can be defined as the concepts, habits, skills, arts, instruments, and institutions of a given people in a given period, or as the response of a given people in a given time to their environment.) In Western medieval culture the fundamental principle of true reality and value was an infinite, supersensory, and superrational God. This is an "ideational" culture. All authority, all bounty, all punishment, flowed from God. At the end of the twelfth century, in response to new challenges and new needs, a profoundly different major principle emerged, namely, that true reality and value is sensory. Only what we can see, hear, smell, touch, or otherwise perceive via our sense organs is real. Even if something is there and we cannot sense it, then it is equivalent to the non-real. This principle slowly rose and met the declining principle of the ideational culture, and their blending produced an essentially new form of culture in the thirteenth and fourteenth centuries. Its major premise was that true reality is partly sensory and partly supersensory. This culture is called "idealistic."

As time went on the ideational culture of the Middle Ages continued to decline and the sensory continued to gather momentum. Beginning roughly with the sixteenth century the new principle became dominant. In this way the modern form of our culture emerged--the sensory, utilitarian, empirical, secular culture called "sensate." (Refer to Figure 1.) The explanation of what we see around us and where we are going is simply that the sensate system of modern western culture is disintegrating. We are living at one of the great turning points of human history when one form of culture is declining and a different form is emerging. Like previous turning points or transitions, it is marked by an extraordinary number of wars, revolutions, and anarchistic behavior; by social, moral, economic, political, and intellectual chaos; and by a temporary destruction of the great and small values of mankind. For the past four centuries the sensate culture served brilliantly, giving us the tools which allowed us to reach a point where individual freedom and fulfillment existed as they never had before. Every form of culture is finite in its creative possibilities. When its creative forces are exhausted and all its potentialities realized, it either becomes stagnant or shifts to a new form. When this moment comes, it begins to disintegrate and decline. It is happening to us now. If we cannot stop it, we can at least try to understand its nature, causes, and possible consequences. If we do this, we may be able to shorten its tragic period and mitigate its ravages. This is Sorokin's main idea.

Western culture is not dying any more than it died when Greece fell and Rome took up the burdens of civilization, or when Rome fell and a feudal society strove to keep Western man functioning; but it is changing just as it did in those periods. Sorokin investigates a number of parts of our culture in detail, such as the fine arts, science, philosophy, religion. We will look at a few that have particular interest for us, such as ethics and law. Every society has some laws as to what forms of conduct are expected, required, and permitted on the part of its members. The ideational ethic norms were aimed at union with the absolute, which is supersensory. "Lay not up for yourselves treasures upon earth." Sensate ethical norms regarded pleasure, sensory happiness, and utility as the supreme values (the maximum happiness for the maximum number of human beings). These led to the different forms of ideational and sensate law. Ideational law stated that:

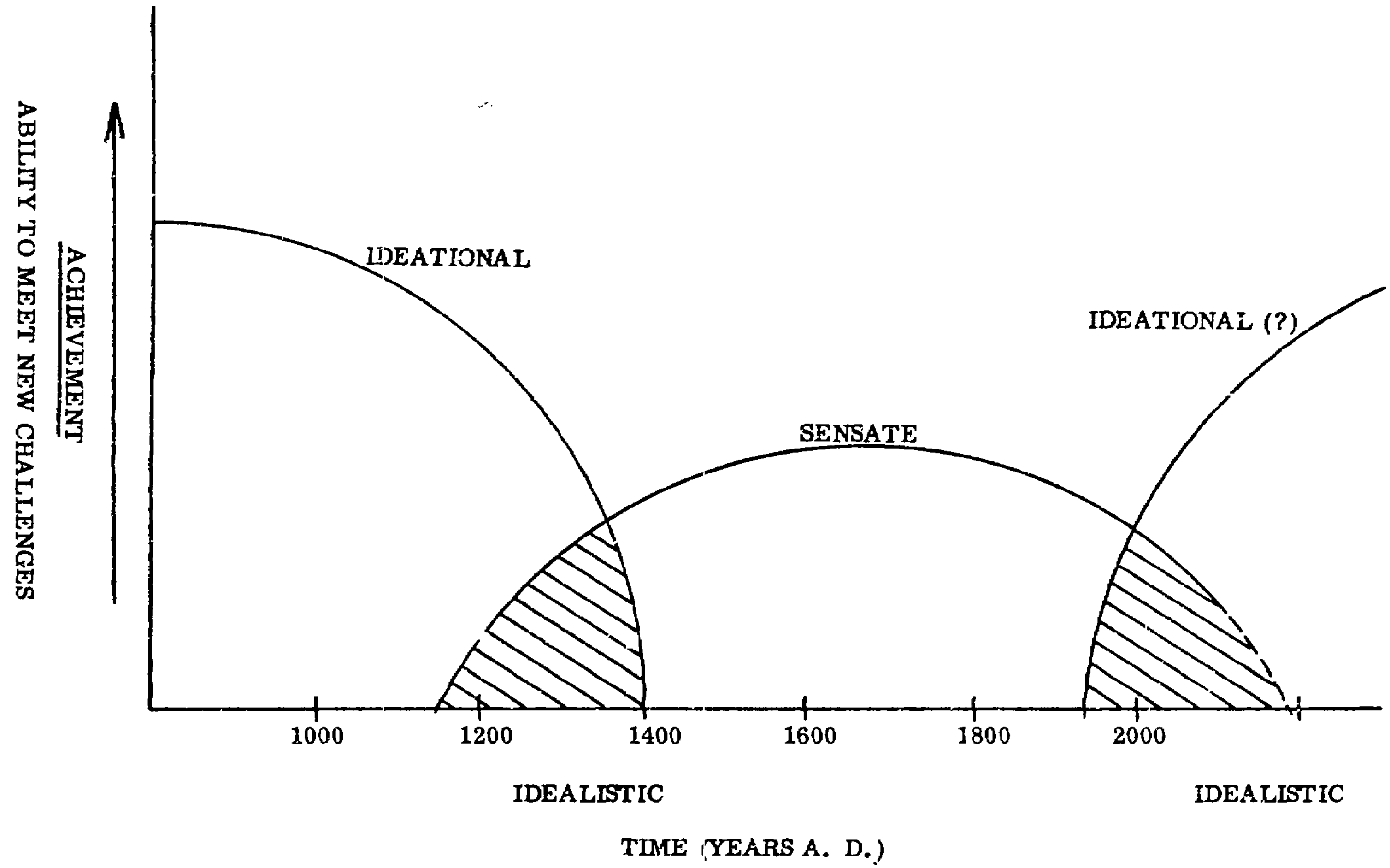


Figure 1. Progress and Transition of Cultures

1. Laws are given by God. As such, they are absolute and cannot be changed for utilitarian or other considerations.

2. Crime and sin are synonymous.

3. Punishment includes supersensory penitance (hell).

For the sensate law we have:

1. It is exclusively utilitarian--the protection of life, property, and the maintenance of peace and order.

2. Norms are relative, changeable, and conditional. Nothing eternal is implied.

3. Virtually ignores theological sins (heresy, sacrilege).

4. No supersensory sanctions.

But one can readily see where sensate law leads. Any sensory value, as soon as it is put on a plane of relativistic and utilitarian convention, is bound to become more and more relative with time until it reaches a stage of "atomization" (as Sorokin calls it) in its relativism and utter arbitrariness in its conventionality. The final stage is bankruptcy, because with random arbitrariness each region, pressure group, faction, or individual has a right to press for what is in its interest. Since hardly any value is common to or equally binding on all the groups (say employees and employers), their interests are usually contradictory. Yet a sensate arbiter in our legal system today can only rule in terms of what is equitable for the contending parties in one particular part of the society. Tomorrow, a different arbiter will rule differently. Everyone will eventually decide to become his own law giver, deeming his standard as good as anyone else's. The result is moral chaos and anarchy.

The situation in ethics and law leads to other areas of interest: criminality, war, and revolution. If a person has no strong convictions regarding right from wrong, if he does not believe in God or absolute moral value (and remember this is the age of situational ethics), and if his hunger for pleasure and sensory values is paramount, what is it that guides and controls his conduct toward other men? Nothing but his desires and lusts. Under these conditions he loses all rational and moral control and common sense. Nothing except physical force can deter him from violating the rights of others. His whole problem of behavior is determined by the ratio between his force and that wielded by others. In a society or set of societies composed of such persons the inevitable consequence will be a multiplication of conflicts and of brutal struggles involving domestic groups and classes as well as nations. Periods of transition from one fundamental form of culture and society to another--when the old socio-cultural edifice is crumbling and no new structure has yet been erected, and when socio-cultural values have become almost completely atomized and the clash of values of different persons and groups become utterly irreconcilable because of the crisis of the law--inevitably produce a struggle of the utmost intensity marked by the widest diversity of forms. Within a society it assumes, in addition to other conflicts, the form of an increase in crime, and especially an explosion of riots, revolts, and revolutions. Remember, this was written over 30 years ago.

Let's look at assassination for a moment. Sorokin doesn't specifically mention it, but it can be classified with criminality as a particular type of murder. The material on assassination is taken from the "Staff Report to the National Commission on the Causes and Prevention of Violence" (October 1969). The Staff Report defines assassination as: "all attacks against office holders." It defines certain preconditions for assassinations in a democracy as follows:

1. Weakening of shared democratic values, or a crisis in which the democratic institutions are incapable of taking effective remedial action. (These words could be taken almost directly from Sorokin.)

2. Defamation and vilification of democratic politicians and institutions. (This justifies to some people the removal of the evil individuals and institutions.)

3. Existence of groups of persons with an ideology and tactics of direct violence.

4. Presence of persons with propensities for violence, once the antecedents are present.

At any rate, between 1835 and 1968 there were 81 deadly attacks on office holders in the United States (16 since 1948). (Refer to Table I.)

TABLE I
Deadly Attacks On Office Holders In The United States
1835-1968

Office	Attempts	Successes	% Of Individuals Holding Office
President	9	5	23
Governor	8	3	0.6
Senator	7	2	0.7
Representative	9	2	0.1
Mayor	10	6	
State Legislator	17	12	
Judge	11	10	
Minor Official	10	7	
	81	47	

Now this is not a large number of people. Besides, is 81 men in a period of 123 years a bad record? To find out, the Staff compared the United States to other nations. They found that the United States, out of 88 countries, has the 13th highest level of assassination attempts for the period 1918-1968, and ranks 5th highest (out of 84) in all assassination events, including plots, in the 20-year period 1948-1967. The authors state that: "Although a precise ranking of countries is impossible, we can say with confidence that the United States falls well within the category of those nations that experience a high level of assassination." If we say, of course, that the United States, with its large population, would have a high occurrence of assassination because there are more people, we would weight the previous data and arrive at an assassination per capita rate. However, assassination rate bears little relationship to population size. There is no evidence that larger countries do, in fact, have more assassinations than smaller ones. If countries are divided into groups according to population, the United States still ranks first among the six countries with populations over 100 million. (See Tables II and III.)

TABLE II
Frequency Of Assassination In Relation to Population
(For Countries Above 50,000,000 Population)

Country	Population	Plots and Attempts, All Persons
United States	190,700,000	16
India	467,700,000	8
Indonesia	101,000,000	5
Pakistan	100,600,000	5
China	710,000,000	3
USSR	227,000,000	0
Brazil	78,700,000	12
Japan	96,200,000	9
Italy	50,650,000	3
West Germany	57,850,000	2
United Kingdom	54,200,000	0

Table II shows the United States deviation from the general rule that high modernity indicates a low assassination occurrence. The conclusions of the Staff Report are:

1. Violence is not random--political, social, and ecological factors are associated with it (i.e., Sorokin's thesis).

2. Assassination shows a similar pattern to internal violence and instability. Whatever is related to violent and agressive behavior within countries is also related to the occurrence of assassinations.

TABLE III

Relationship Between Assassinations and Political Instability For a 20–Year Period – 1948-1967
(Grouped and Summed for Three Periods)

ASSASSINATION HIGH (THREE AND ABOVE)

ASSASSINATION LOW (TWO AND BELOW)

STABILITY 1

Assassination High (0)		
Assassination Low (3)	IRELAND	0
	LUXEMBOURG	0
	NETHERLANDS	0

2

Assassination High (1)	GHANA	7
Assassination Low (11)	NEW ZEALAND	1
	SAUDI ARABIA	2
	SWEDEN	0
	AUSTRALIA	2
	CHINA–TAIWAN	0
	FINLAND	0
	WEST GERMANY	2
	ICELAND	0
	DENMARK	0
	AUSTRIA	1
	UNITED KINGDOM	0

3

Assassination High (3)	ITALY	3
	ISRAEL	3
	MEXICO	3
Assassination Low (12)	NORWAY	0
	SWITZERLAND	0
	CANADA	1
	AFGHANISTAN	2
	COSTA RICA	2
	ROMANIA	0
	LIBYA	1
	ETHIOPIA	2
	LIBERIA	2
	URUGUAY	0
	CHILE	0
	BELGIUM	1

4

Assassination High (21)	MALAYA	6
	JAPAN	9
	DOM. REP	7
	UNITED STATES	16
	NICARAGUA	5
	ECUADOR	3
	PAKISTAN	5
	IRAN	19
	INDIA	8
	CAMBODIA	6
	CHINA–MAIN	3
	CZECH	5
	PHILIPPINES	15
	CYPRUS	5
	JORDAN	6
	THAILAND	3
	TURKEY	4
	MOROCCO	17
	BRAZIL	12
	UNION SO. AFRICA	3
	FRANCE	14
Assassination Low (10)	ALBANIA	2
	BULGARIA	0
	YUGOSLAVIA	2
	CEYLON	2
	SPAIN	2
	USSR	0
	SUDAN	1
	HUNGARY	1
	POLAND	0
	PORTUGAL	2

5

Assassination High (18)	PANAMA	5
	TUNISIA	16
	LAOS	10
	PARAGUAY	3
	EGYPT	14
	LEBANON	12
	GUATEMALA	12
	GREECE	5
	KOREA	20
	HAITI	5
	SYRIA	7
	VENEZUELA	12
	BURMA	5
	COLOMBIA	7
	IRAQ	5
	CUBA	28
	BOLIVIA	9
	ARGENTINA	9
Assassination Low (4)	EL SALVADOR	2
	HONDURAS	0
	EAST GERMANY	0
	PERU	0

INSTABILITY 6

Assassination High (1)	INDONESIA	5

a. More specifically, a high rate of assassination is directly related to frustration within the "system" (external aggression, minority tension, homicide rates, and general political violence).

b. The higher the level of modernity and the higher the level of suicide, the less likely that assassinations will occur.

However, as noted before, the United States deviates from this pattern somewhat. In general, there is a tendency for "modern" high mass consumption societies to have a low frequency of assassination. However, the United States and France are exceptions. We are in fact classified as completely deviant, having all the factors supposedly conducive to political stability, such as high modernity, low systemic frustration (social wants easily satisfied), low rate of socio-economic change, and permissive governmental structure, yet we are termed unstable and politically violent. The Staff Report admits to no satisfactory explanation for this. I must say that the Staff Report's work is exhaustive and exposes numerous interrelated issues. The phenomena of political violence and murder are a complex thing, and I don't want to give you the impression it is a simple matter. However, time allows only touching on the highlights of the Report.

Where, then, does this leave us. Sorokin offered a diagnosis 30 years ago of what is ailing us. He may be wrong in detail, but he cannot be wrong in general because we are a species still evolving. Men, a few centuries hence, will look back with a shudder at our primitive existence, just as we now look back on prehistoric man. There are bound to be "ups" and "downs" in this progress.

The Staff Report fills in details concerning one aspect of life in our times. It says we are a violent, unstable society, and that as internal violence increases so too will assassinations. And Sorokin tells us violence will increase as the crisis in Western culture deepens. I think the situation is pretty well described by my two sources. Therefore, we must energetically develop equipment to detect weapons and explosives not only for the protection of office holders, but also for other key elements of our society, such as energy sources and communications. Perhaps such vigilance can prevent the worst of the outrages which are sure to happen, or at least lessen their intensity.

A speaker ought to end his talk on an "up-beat" note. Today, I cannot. I wish I could. Perhaps, the fact that development of equipment and some hard thought have started is promising.

I wish to thank E. P. Dutton & Co. for their permission to quote from "The Crisis of Our Age" by P. A. Sorokin, Copyright 1944, E. P. Dutton & Co.; renewal, copyrighted 1969, by Helen P. Sorokin, Dutton

paperback edition, published by E. P. Dutton & Co., and used with their permission. I must also emphasize to you that this paper represents my personal views and in no way reflects AMC or DA views or position.

THEORY AND APPLICATION OF MAGNETIC WEAPON DETECTORS

By: James H. Henry, Institute for Defense Analyses (IDA)

The device most frequently suggested for detecting the presence of a concealed handgun or grenade is a metal detector. Indeed, it is an old proposal and, as we shall see, it has its difficulties.

It is my role in this symposium to set the stage for the speakers who follow and who will discuss particular instruments and programs for detecting handguns, concealed handguns, and other metallic weapons. Despite the title of my paper, I will not present the theory of metal detectors (a complex subject at best). Rather, I hope to establish a background and an understanding of the nature and problems of metal weapons detection and metal detection techniques--what they can and cannot do. After reviewing particular aspects of metal detection history, I shall present, in simplistic terms, the elements to be considered in metal detection. I shall mention some of the quantities that are subject to measurement and indicate the instrumentation problem under operational conditions.

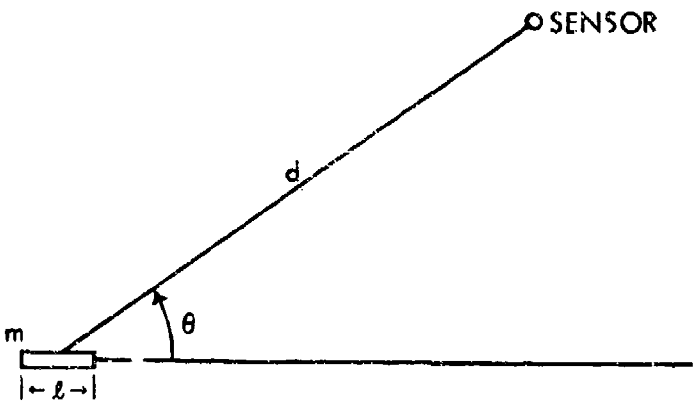
Historically,[1] the first reference to gun detectors was in a patent filed by C. N. Clark on 12 April 1895 (Patent No. 541, 719). Clark placed in a building a large air coil electromagnet connected to a galvanometer relay. He claimed that when persons came near to or walked away from the coil, the needle of the galvanometer would be deflected. In his patent application, Clark stated, "It is further understood, that any stationary iron in the magnetic field would not produce a deflection. But, whenever a person having metal upon his body moves into the magnetic field or away therefrom, the galvanometer is actuated. On the other hand, a piece of soft iron may be suspended or arranged near the coil, so that when a person not having any iron on his body approaches or moves from the magnetic field, the jarring of the floor or other part of the structure causes the soft iron to vibrate and disturb the magnetic field of the coil and consequently, causes a deflection of the galvanometer." The idea, then, of gun detection based on magnetic principles is at least 77 years old.

A number of other patent applications followed. In all, they attempted to measure a change in the magnetic field, one usually lying between a dc electromagnet and a pickup solenoid. Most of the "inventions" were rudimentary. One developed by J. C. Becker (et al.) in the early 1930s was somewhat more sophisticated. It used an alternating current and a pair of long solenoids concealed in a doorway. Perhaps this was the first of the Portal Detectors developed. It was, however, defective in that its field shape and direction were such that it proved to be an unreliable gun detector. In true patent application language, Becker's specifications contained the words: "... it will be realized that whereas we here have shown and described a practical and operative device, nevertheless, many changes might be made in the size, shape and number, and disposition of the parts without departing from the spirit of the invention." One theme of my remarks is contained herein--"There are many changes possible." Other devices have been developed and patented, and yet, it seems there is much more that can be done in the field of concealed handgun detection.

A substantially improved detector was patented by D. G. C. Luck in July of 1934. (Incidentally some 10 years ago, Luck worked at IDA. At that time he was trying to devise ways by which guns could defend against ICBMs.) I won't describe Luck's gun detector device, but in his description he wrote: "...that an unbalance of one part in 20 millionths is thus easily observable. At such sensitivities masses as small as shoe nails in the protected region begin to be indicated, while such objects as a small gun or a set of brass knuckles give a tremendous effect. This, however, is an exceptional condition. In the normal installations, the device is adjusted to give the alarm on the smallest types of guns. Unfortunately, the same sensitivity will also detect such bodies as tobacco tins, spectacle cases, trusses, and in particular, steel arch supports which many people unknowingly wear in their shoes. This fact limits the major usefulness of the device to conditions under which the cause of each alarm can be investigated and some embarrassment to innocent persons is not a disadvantage. That is, such a device as this is useful for arms smuggling into penal institutions or metal pilfering from industrial plants, as well as for the detection of metal in package goods, such as foodstuffs or textiles; but it is of little use for purposes like protection of commercial banks or stores from armed robberies." This refers to the false alarm problem that remains today.

With that introduction then, let us now examine some specifications or requirements that enhance the usefulness of metal detectors. Obviously, we would like to have a high probability of detection at an adequate range. At the same time we would like a low false alarm frequency. It should not be necessary to have a human observer. The device should be portable and should record what is sensed. Furthermore, it should be conspicuously visible so that it will deter criminal activity.

Now a note on the mathematics of metal detectors (Figure 1). This is one form of the statement showing the elementary relationship for metal detectors. In the figure, the metallic weapon (perhaps a gun) is represented by the magnet. At a distance d from it, you have an instrument searching for the presence of the gun. The degree of magnetism in the gun (called its magnetic moment) is represented by m. Its major dimension is ℓ. The distance from the sensor to the gun or the magnet is d. The strength of the field from that gun (its magnetic field) varies inversely as the cube of the distance. For example, if you had an instrument capable of detecting one kind of magnetic material with a magnetic moment of one at a distance of 1 foot (or unit distance), it would be unable to distinguish this from an object having a magnetic moment of 27 at a distance of only three units. In other words, this inverse cube relationship dominates, setting requirements for sensitivity and masking. A second class of sensors induces a magnetic field in the weapon. This is called an active sensor. The induced magnetic field in the weapon itself is detected. Here, we have transmission and reception (i.e., both ways), and the law here is that the sensitivity falls off inversely as the 6th power of the distance. Thus, metal detectors come in two classes: those that try to measure the local modification of the ambient magnetic field (passive) and those that induce eddy currents with resultant local magnetic field changes. The latter are capable of detecting all metal objects, not only those made of magnetic materials.



$$\text{for } d >> \ell, \quad H = \frac{\ell m}{d^3} \left[1 + 3 \cos^2\theta \right]^{1/2}$$

Figure 1. Mathematical Relationship for Metal Detectors

Devices for measuring the intensity of a magnetic field are called magnetometers. They are classed as absolute or relative, depending on whether they are capable of being calibrated without direct comparison with a standard magnetic instrument. In weapon detection we are normally concerned only with relative magnetometers. Perhaps, the most common is the flux gate saturable core magnetometers. These instruments have some advantages over the older types of relative magnetometers. In essence, the instrument has a sensing element or core of permalloy, or similar material which becomes magnetically saturated in very low magnetic fields. There are two coils wound on this core. One coil surrounding the core excites it to mean saturation at a basic oscillator frequency. When there is no externally applied magnetic field, the alternating magnetic flux induced in the second coil is symmetrical or balanced in both halves of the alternating field. But, an external magnetic field along the axis of the core causes it to approach saturation more quickly during one-half of the cycle, so that the resulting flux is asymmetric These saturable core magnetometers were developed during World War II for use in airborne detection of submarines. I realize that this explanation is superficial. Furthermore, there are a number of variations.

As to sensitivity and units, we have already indicated a possible sensitivity of one part in 20 million. Indeed, we can do a good deal better than that. The unit of magnetizing force is called the oersted, and when multiplied by the permeability, the magnetic flux or magnetic induction is calculated. The latter is measured in a unit called the gauss, and 1/100,000 of a gauss is called a gamma. The earth is a magnet having a magnetic field in the region of the equator of .30 to .40 oersteds, and at the poles .60 to .70 oersteds. This is the magnitude of the ambient field. Guns, for their part, can have magnetic moments ranging from zero (you can demagnetize a gun) to factors of several thousand gammas. The magnetic moment of a gun is highly dependent on the gun's hardness, its thermal and shock history, the ambient field in which it is in, the relative position of the components, and so on. Guns are not very constant in their magnetic moment and are subject to change.

Now let us consider some of the variables that we can measure. I am going to ignore passive magnetometers, primarily because of the difficulty of getting a satisfactory range, and also because of their great tendency for registering false alarms.

The active sensor devices already mentioned are more popular. These induce an eddy current by alternating electric current field coils, and one of the possible variables is the frequency of the alternating current. Two potential measurements are losses. One is caused by the demagnetization of the gun itself and is called the hysteresis loss. It is proportional to the frequency and the 1.6 power of the field strength. The other is the eddy current loss (loss induced in the target by the alternate magnetic field) which is proportional to the square of the frequency and the square of the induction. With simultaneous measurements at different frequencies and different fields, one can estimate the properties of the material being observed.

Finally, we list four items which we can measure, but not necessarily with ease. We can measure the conductivity of the material in the magnetic field. We can measure the permeability (the thing that relates the magnetic force to the induction). We can make estimates of the size of the device, although in a fairly complicated fashion. Finally, we can make a calculation or a determination of the position of the gun. There are other things that can be measured, but the aforementioned items are the principal ones that most of the magnetic detection devices seek to acquire.

Some of the problems should be mentioned. I have already mentioned the difficulty of camouflaging. A larger object can be camouflaged by a smaller object. Things like toy guns can cause a problem if the metallic composition is similar to that of a regular gun. Furthermore, there is a noise in the magnetic field on the earth which undergoes change because of power lines and electrical devices. Some weapons are non-metallic. Perhaps the most pressing problem is that of false alarms. Usually, when making an observation of an individual, there is more than one metallic object on his person.

These introductory remarks, which are not really theory, are intended to give you an idea of metal detection and its problems. In practice, increased detection probabilities can be achieved, at a price. Currently, emphasis seems to be on producing a weapons detection device that costs under a thousand dollars, or thereabouts. I suspect that a really satisfactory instrument at this price is not feasible. However, it may be possible to exploit the techniques recently introduced in geophysical prospecting and in mine detection. An expensive R&D program (perhaps in the millions of dollars) could develop a device that might cost fifty-thousand dollars, with accompanying improvements in portal detection for controlled access situations.

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1 The material in this section is drawn from the unclassified Introduction of "A Weapon Detector," Paul Baran and Harold Steingold, RM 5011 ARPA, July 1966, SECRET.

PORTAL DETECTOR DEVELOPMENT

By: Nicholas Mogan, Intrusion Detection Division, CM/CI Department, USAMERDC

Portal Detectors are walk-through type weapons detectors which are normally used at entrances to controlled areas. Sometimes they are referred to as access control systems.

The development work at the Mobility Equipment Research and Development Center (MERDC) involves the use of portal detectors for two different applications, with accordingly different design goals. One of our missions is the development of a highly sophisticated detector for the protection of key public figures. This scenario requires very high detection reliability and extremely low false alarm rates. The chance of detecting a .32 calibre or larger gun must be 99 percent or better, while the number of false alarms must be kept to about 5 percent. This would allow the authorities to handle suspects in the proper manner. It is expected that only a limited number of this type of detector will be needed; therefore, cost factors are not of primary importance. The emphasis is on detection performance. Cost, weight, power consumption, and operational complexity are not critical, although every attempt will be made to achieve a cost-effective design.

The second type of detector is being developed mainly for military applications. It is intended to be used at check points for screening individuals entering a restricted area. In many cases it is not critical if a small percentage of weapons get through the check point. This detector must be portable, easy to install, simple to operate and maintain by the troops, suitable for battery operation, and designed for low-cost quantity production. The projected detection reliability is 90 percent for .32 calibre or larger weapons, with a 10 percent false alarm rate.

At this point, I want to define detection reliability and false alarms. Take a number of samples representing the commercially available weapons. Let's say we select 10 weapons of different sizes (.32 calibre or larger) and we carry each weapon, in random positions and orientations, 10 times through the detector, making a total of 100 passes. If we get 90 detections, then the detection reliability is 90 percent for that group of weapons. By false alarm we mean a weapon indication from any non-weapon object normally carried by people.

All the portal detectors presently in use are essentially metal detectors, either passive magnetic or active electromagnetic. The first passive magnetic portal detector at MERDC was built in 1965. It was called the Magnetic Concealed Intrusion Detector (MCID) and utilized both the principle and the electronic components of a passive magnetic intrusion detector. This portal detector was field-tested in the Dominican Republic during the 1966 uprising. The reports indicated that the detector was useful, but not suitable for operation on the streets because of moving vehicles. The test results indicated that adequate detection reliability could not be obtained with a reasonable low false alarm rate. It was concluded that in order to improve detection versus false alarm rate, an active system would have to be used.

MERDC developed its first active portal detector in 1966 (Figure 1). Two experimental models were built of plywood. The main objective was to establish a uniform field which would result in a signal amplitude independent of the orientation and position of the target within the detection zone. Very good uniformity (about 2:1) was achieved by using large rectangular transmitter coils on each side of the portal. Also, one receiver coil was used on each side, overlapping the transmitter coil for zero-mutual coupling. This means that no voltage will be induced in the receiver coils if no metallic object is present within the portal.

Although the design objectives were met, we experienced several problems during the evaluation of this detector. One was the shoe problem. Arch supports, which are built into most of the better shoes, caused alarms since the shoes were near the bottom coils. A minimum separation of 12 inches between the shoes and the bottom coils was required in order to minimize the shoe signal. Other disadvantages were the large size of the structure and the time consuming effort of balancing the coils each time the detector was set up at a new location or when large metal objects, like steel desks or cabinets, were relocated in the vicinity of the portal.

The development of the electromagnetic portal detector (refer to Figure 1b, symposium paper "Integrated Access Control System," by L. J. Nivert) was resumed in 1969 under the "Protection of Key Public Figures" project. One task of this project was the development of an Integrated Access Control System consisting of an early warning electromagnetic portal detector and a short pulse X-ray personnel inspection system. Only the electromagnetic detector is covered in this paper. The X-ray system is covered in Mr. Nivert's presentation.

In addition to uniform sensitivity, the portal detector was built in accordance with the following new design objectives. First, we wanted to reduce the size so that the detector would be more portable. We decided to eliminate the mechanical ties between the left and right side of the portal, thus making the detector more suitable for covert inspection. Naturally, we can't tolerate false alarms from shoes. If we want to detect stainless steel guns, the system must also be sensitive to conductive materials. During related R&D efforts MERDC developed systems for obtaining and displaying the phase angle between the signal voltage and the transmitter coil current. It was decided that this information will be used for better discrimination between targets and metal clutter items. A wider range automatic balancing was also needed to make the manual balancing less critical. To obtain test data on the potential advantage of simultaneously using two frequencies one unit was designed to operate at either 380 or 1500 Hertz. Last but not least, the portal detector had to be interfaced with the X-ray inspection system.

The two portal detectors developed for use as a component of the Integrated Access Control System are called PDS I and PDS II. Both detectors have the same basic coil design as shown in Figures 2 and 3. The two rectangular lateral coils facing each other are producing a horizontal field, while the eight solenoidal coils connected in series are producing the vertical field.

The PDS I detector (Figure 4) consists of two 1-foot diameter columns. This unit, operating at a relatively low frequency, is mainly sensitive to ferrous material, although it still is able to detect stainless steel guns with ferrous barrels. The second unit, PDS II, is very similar to this one, but has a shield outside of the coils. PDS II works at approximately 1500Hz and, using phase information, it can discriminate between ferrous and non-ferrous objects.

The PDS II was evaluated at MERDC for false alarm rate. It was found that the solenoid channel was too noisy; therefore, it was disconnected during the tests. Using the lateral coils only, about 95 percent of the medium size hand guns were detected while 6 percent of the office personnel caused alarms with normally carried metallic items, excluding briefcases and ladies' handbags. Comparing the performance of the PDS II with the British Rank detector, which was also evaluated at MERDC, the PDS II was found far superior.

With the active detectors, concern was expressed over the effects on patients with cardiac pacemakers. In cooperation with Walter Reed Army Hospital, both the PDS I and PDS II were tested with patients having cardiac pacemakers. Thirty-nine patients with nine different types of pacemakers were studied. Each patient stood for at least 30 seconds next to the transmitter coils while his heart function was monitored on an EKG machine. It was determined, and I quote:

> "There was not a single instance of a change in rate of the firing pacemaker, a failure to sense of the demand pacemaker, or a failure to pace in the appropriate setting. In conclusion, the PDS I and PDS II Portal Detector Systems had no effect on the pacemakers tested."

During 1971, Westinghouse Electric developed a portal detector (Figure 5) called the WD-4 weapon detector. This detector operates on two frequencies (about 100 and 1000Hz) simultaneously. The signal processor compares the phase angles of the signal obtained on the two frequencies. This method leads to extremely good discrimination between weapons and clutter items. The detector was tested and evaluated by the FAA and the Transportation Systems Center, Cambridge, Massachusetts. Comparing the WD-4 with the PDS II, the Westinghouse detector seems to have better detection reliability for small weapons. Because of its extremely good detection reliability, it was decided to procure two modified WD-4 units for the Protection of Key Public Figures program, even though their large tunnel-type structure is very difficult to conceal.

Our present active portal detector development effort includes two types of equipment: one, an improved PDS detector; and two, a modified Westinghouse detector.

As a result of an in-house experimental effort, the signal-to-noise ratio of the PDS I and II was greatly increased, expecially in the solenoid coils. This was achieved by winding a coil of a few turns directly onto the transmitter coil. This coil, called a bucking coil, is connected in series opposing with the receiver coil. A much better null could be maintained in this manner than by using a bucking transformer within the electronic package. This method will be incorporated in the next two improved portal detectors. Better discrimination will be achieved by improving the phase angle computation. The weight of copper wiring will be reduced since the improved signal-to-noise ratio requires less ampere-turns. A new type of receiver electronics will result in lower cost. An additional feature will be the target position indicator which can discriminate between targets in the upper, center, or lower third of the portal. Another feature will be the use of two receiver columns with one transmit column. People can go through in two lines, allowing the detector to handle more traffic. The Westinghouse detectors will be modified to reduce the size of the portal, making it compatible with a revolving door; and the electronics will be improved, resulting in better detection performance.

The block diagram of the PDS detectors being built is shown in Figure 6. Separate frequencies are used for the transmitter coils and receiver coils to avoid cross-talk, a technique similar to that employed in PDS II. By using two receivers for both the lateral and solenoidal coils, we can obtain the position indication. Beside the bucking coils the nulling coils are shown; they are used to obtain the reference voltage for the automatic nulling circuit.

The different applications of the PDS detectors are shown in Figure 7. The units can be set up anywhere in a hallway; or if the hallway is narrow, they can be placed behind walls. The lower picture shows the application of the dual passageway, the transmit coil in the center and the two receiver coils, right and left.

In addition to hardware development, an extensive R&D program will be carried out investigating the signatures of various targets in the PDS in both the time and frequency domains. This work, which utilizes digital computer technology, may lead to discrimination between briefcases and handbags with and without a gun inside. At the present time neither the Westinghouse nor the PDS detector has this capability.

It was mentioned earlier that any passive detector has its inherent limitation concerning detection reliability versus false alarm rate, while the relatively low cost and very low power requirements (suitability for battery operation) are definite advantages of these devices. The development of our thin strip line sensors for intrusion detection gave us an opportunity to consider the use of these sensors for a passive portal system. One advantage of the line sensor over the point sensor is its uniform sensitivity along a line parallel with its major axis. A disadvantage of the passive system is that magnetized small steel items can give as big or even a bigger signal than a hand gun. This problem can be overcome by the use of a DC field produced by DC current or by strong permanent magnets. This will definitely be necessary if the detectors are to be used on the streets. The increased field within the portal will reduce the effect of distant moving objects.

Considering these features, it is expected that a reasonable detection versus false alarm rate can be obtained, although the performance of a highly sophisticated active portal detector will not be matched. In those situations where occasionally missing a weapon is not critical, a passive portal detector certainly has its merits. For example, such an application would be the screening of the general public for concealed weapons. I think such a detector could be used in those states where the law prohibits carrying a concealed weapon.

In February, MERDC initiated the in-house development of a passive portal detector using thin strip line sensors. Two approaches were considered. In the first, sensor strips are taped to an existing door frame (Figure 8). In this case, the complete system will fit in an attache case. Since the sensor strips are inexpensive, they are expendable (and can be left in place). The electronics can be used with new sensor strips. The production cost for one complete package is expected to be under $300.

The other configuration has its own frame or portal. This allows more freedom for the sensor design which can result in a lower false alarm rate. The portals can be folded into a flat, easily portable package. An experimental detector (Figure 9) was built at MERDC. The horizontal wire loops are primarily sensitive for vertically oriented targets, while the vertical loops are for horizontally oriented targets. The expected production cost of the complete system is under $500.

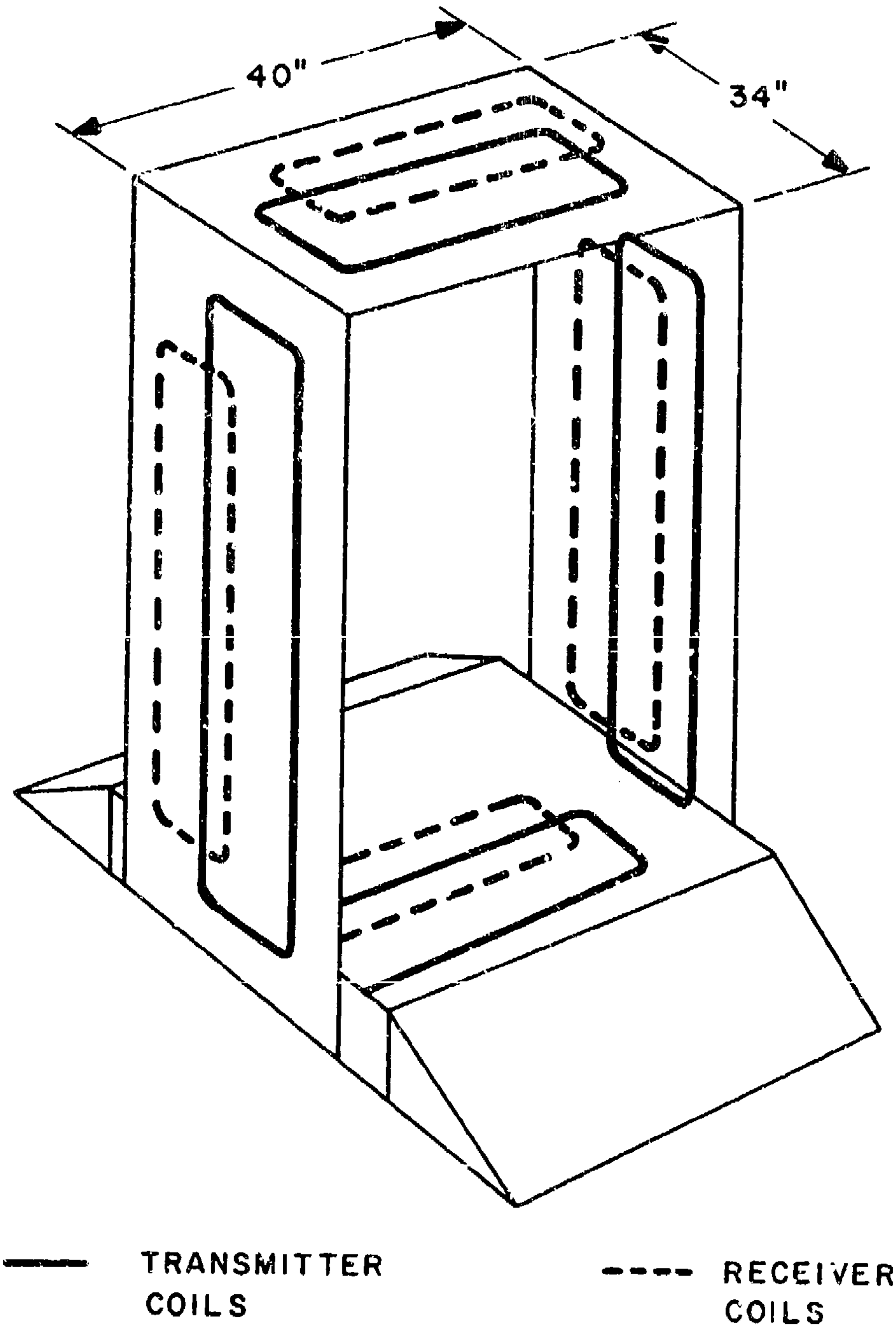


Figure 1. Active Portal Detector

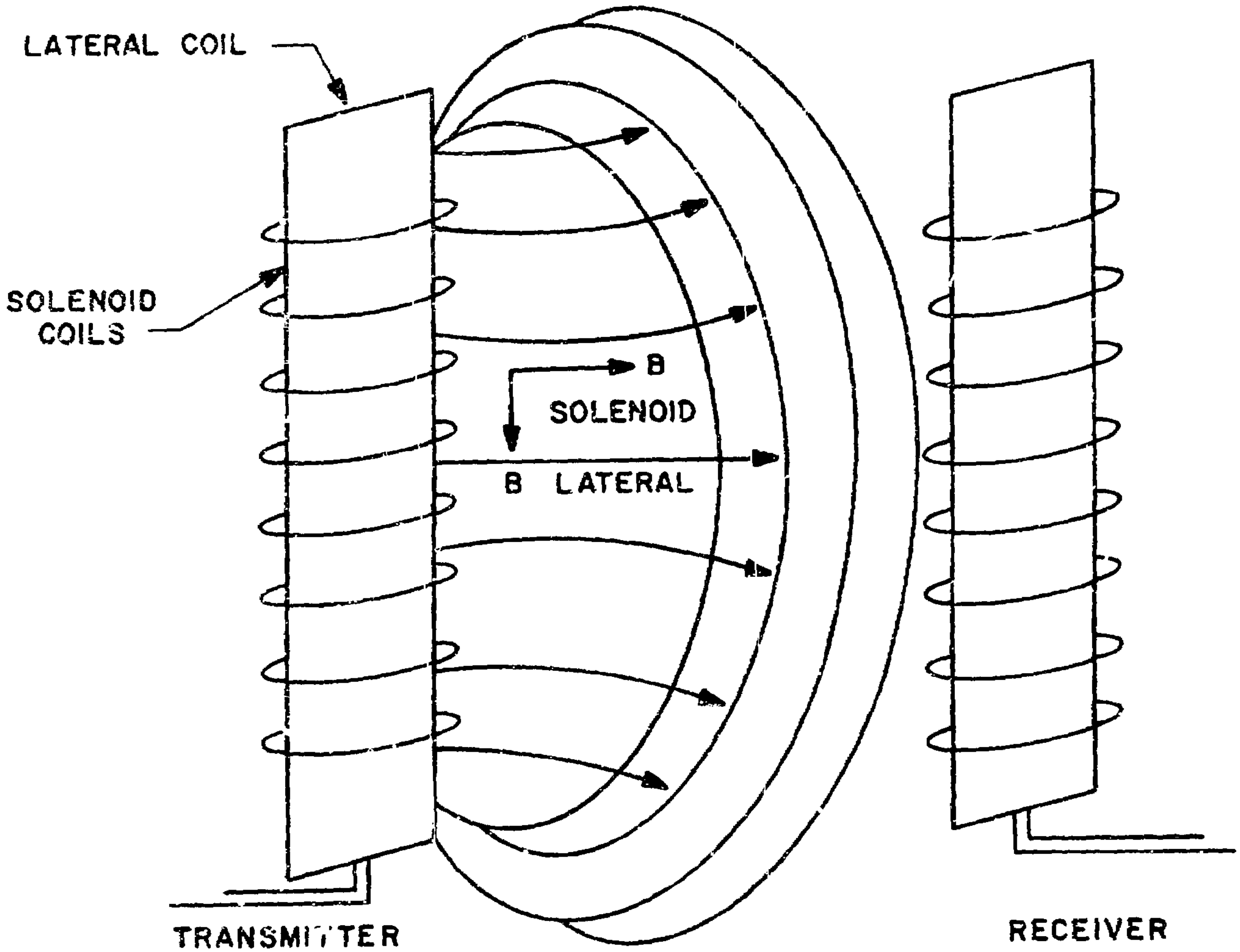


Figure 2. PDS Coil Design

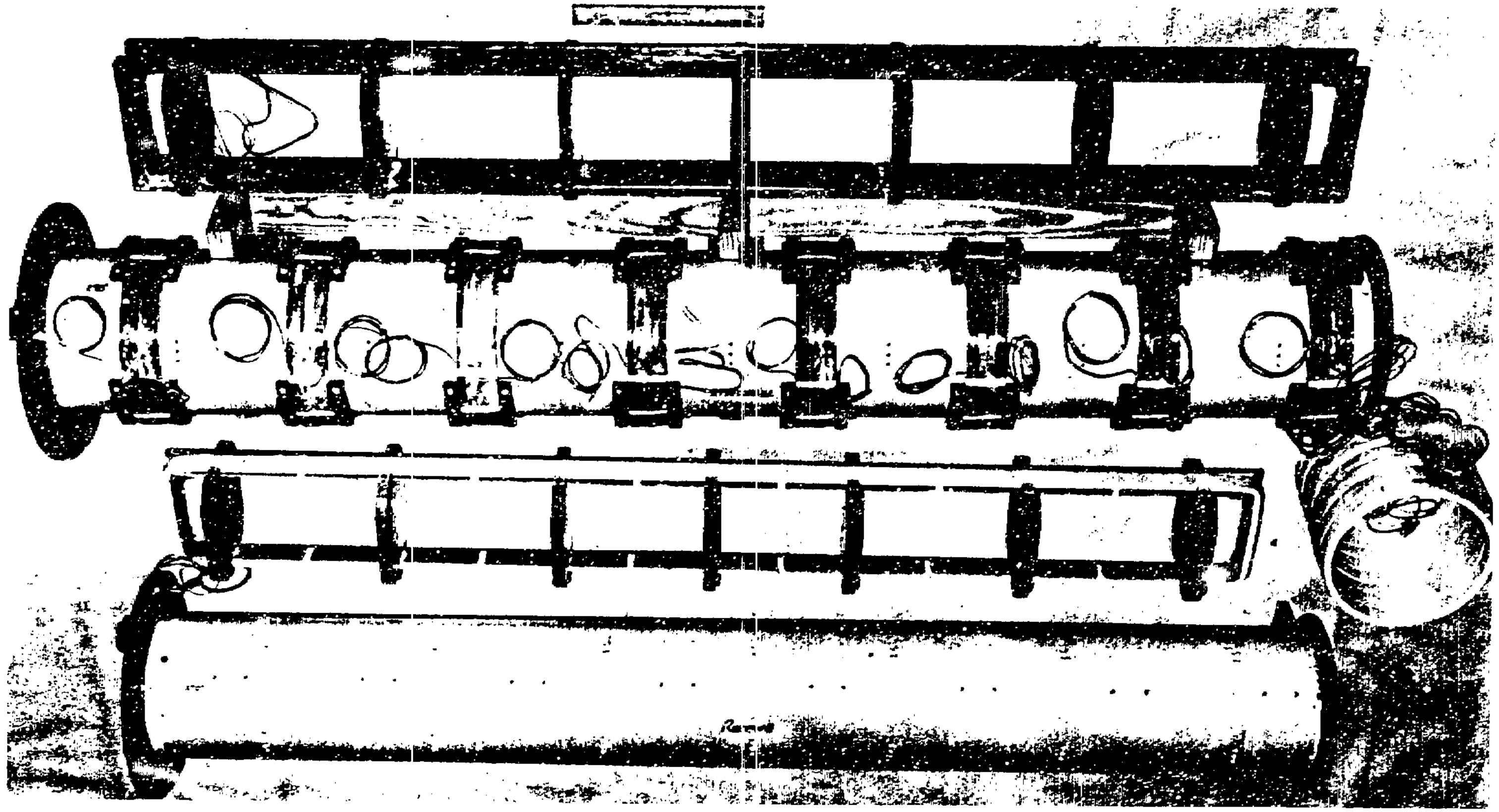


Figure 3. PDS I and PDS II Coil Design

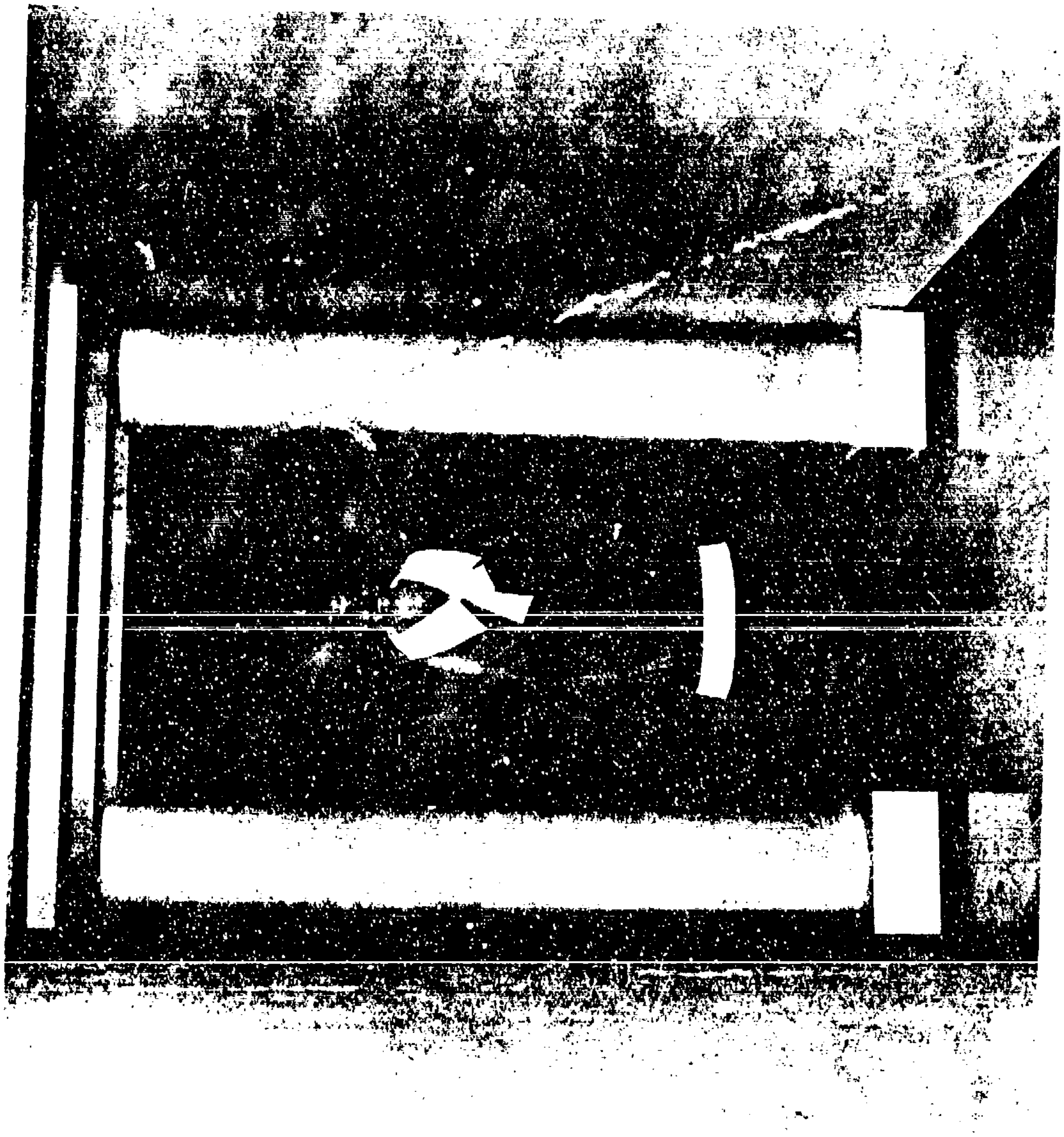


Figure 4. PDS I Detector

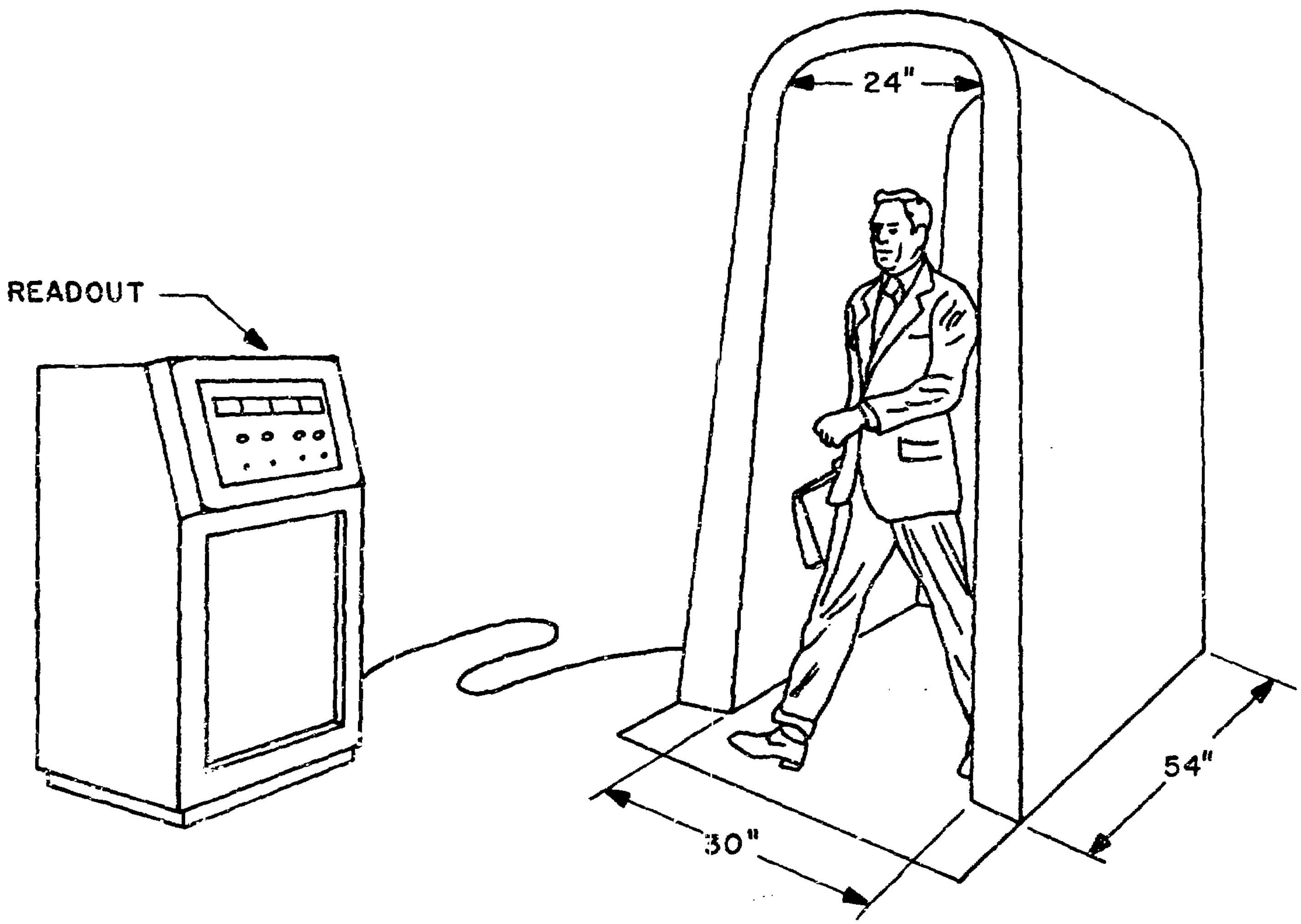


Figure 5. Westinghouse Weapon Detector

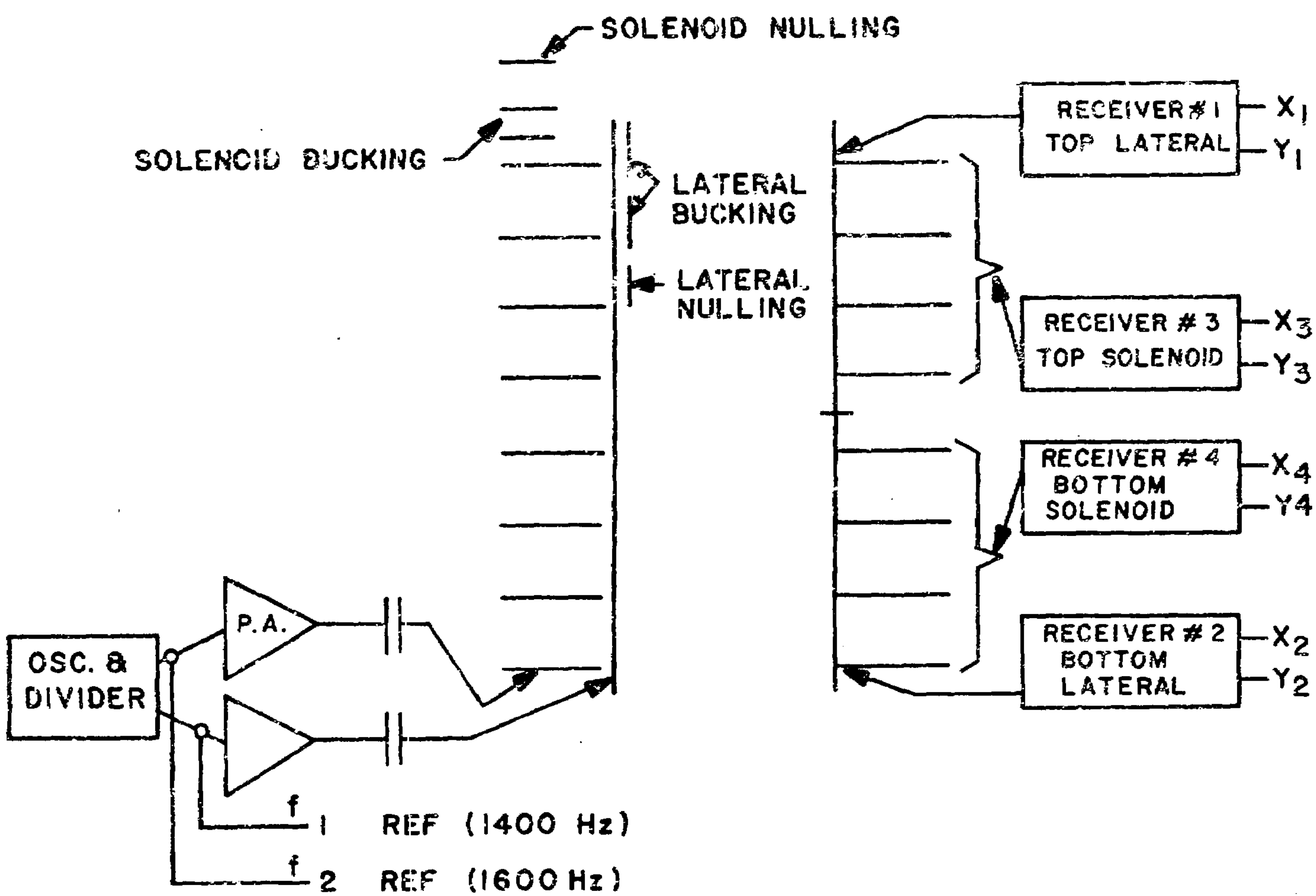


Figure 6. PDS III Block Diagram

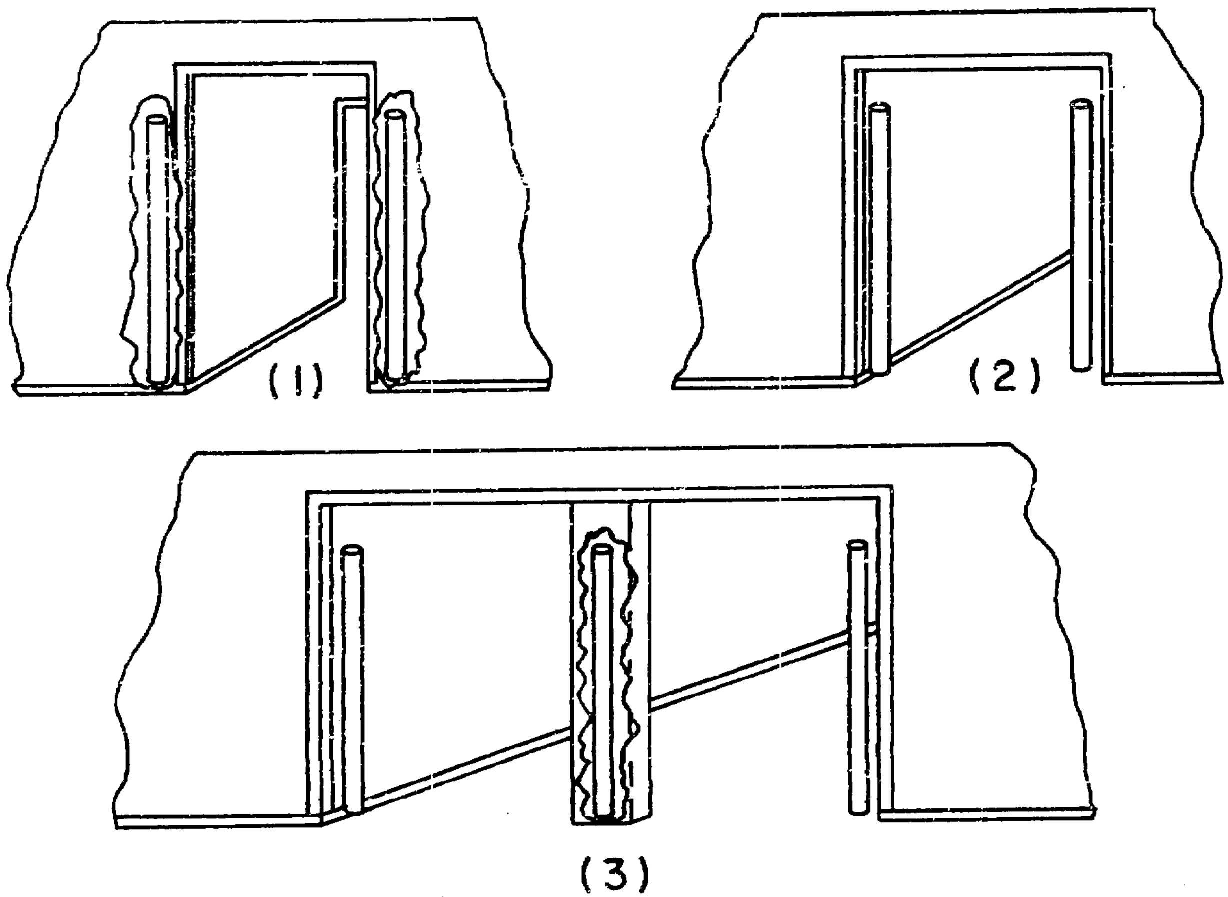


Figure 7. Possible Installations--Active Magnetic System

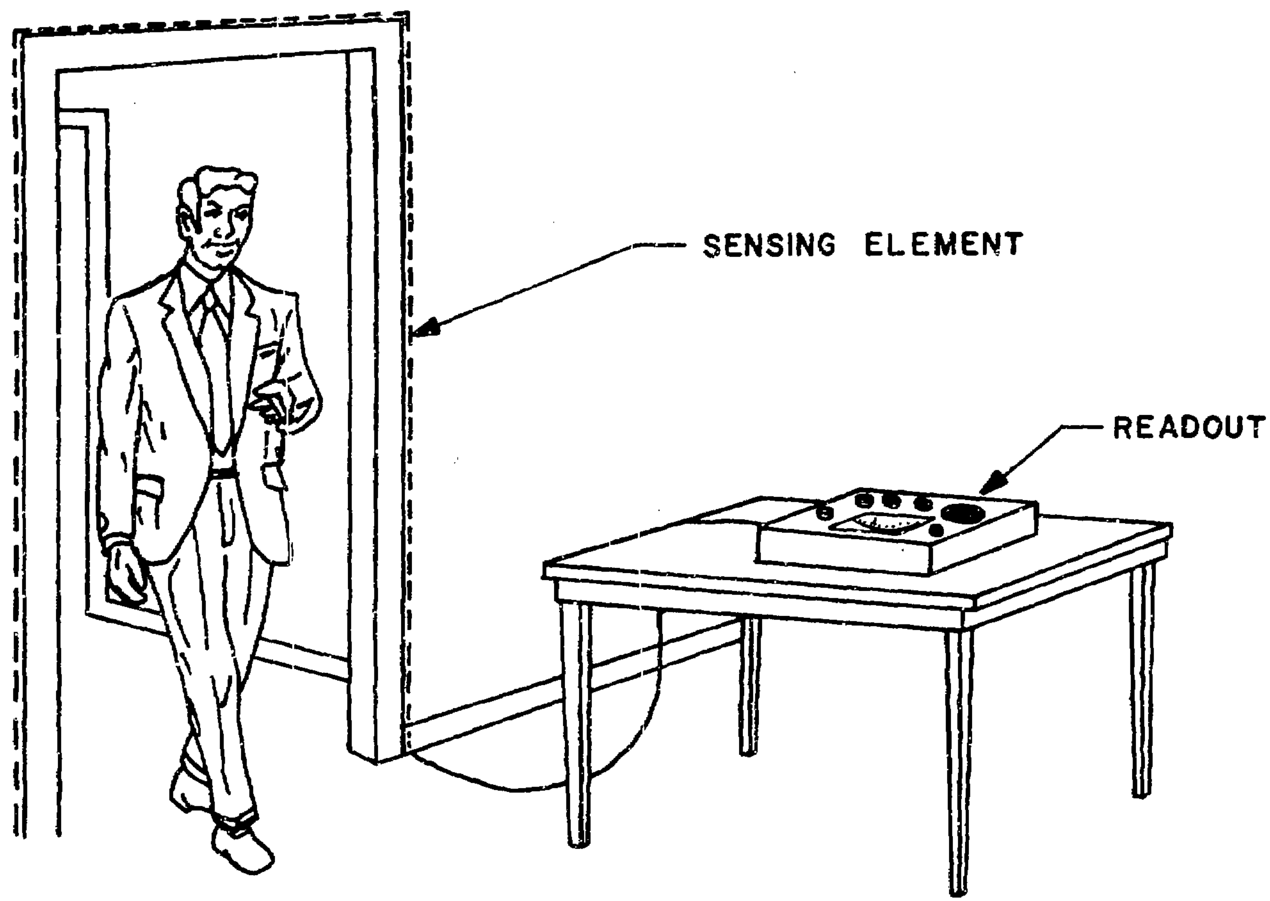


Figure 8. Passive Magnetic Detector

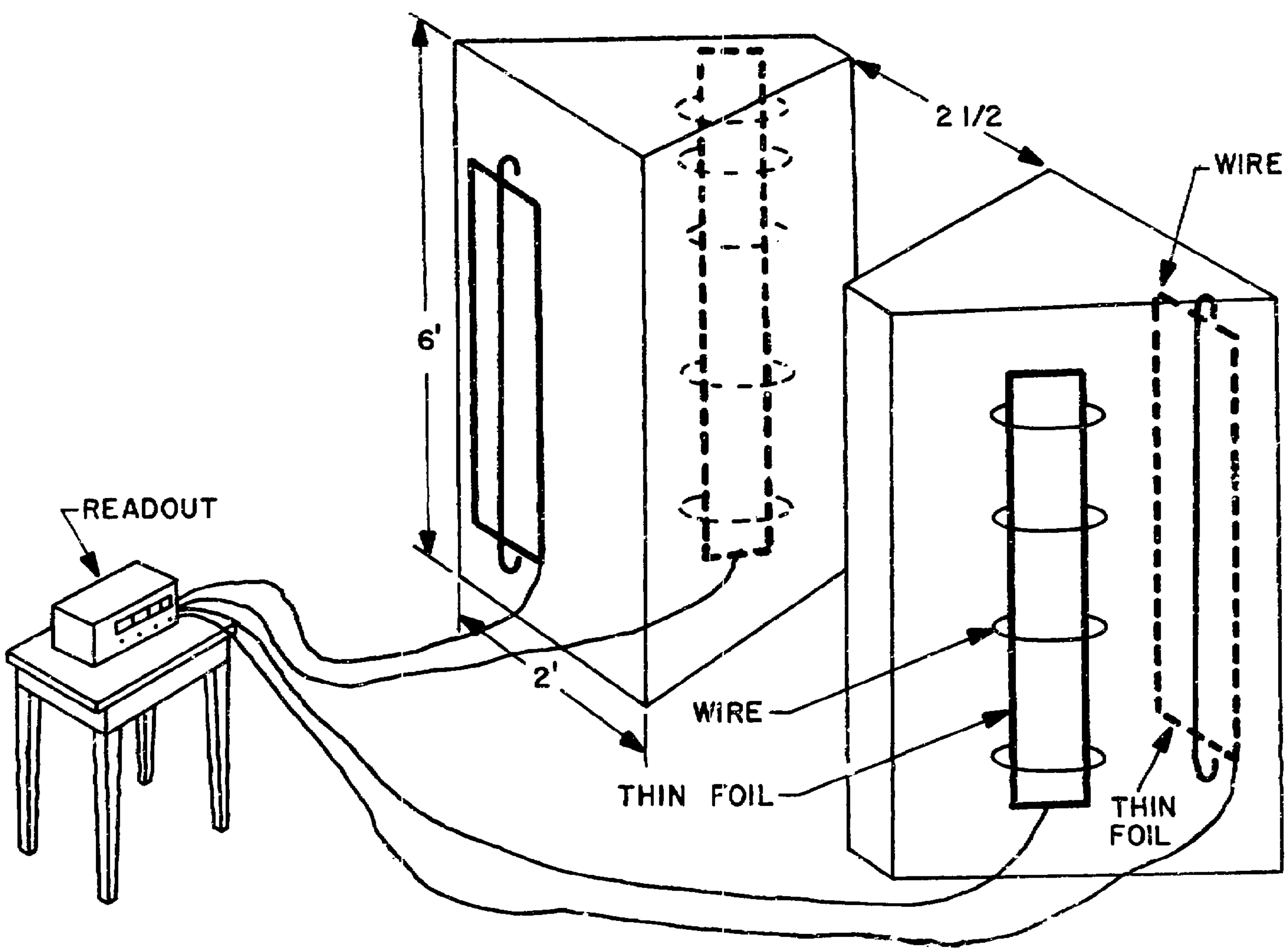


Figure 9. Passive Portal Detector

A FEASIBILITY STUDY OF WEAPON DETECTORS FOR PARCEL INSPECTION APPLICATIONS

By: Howard Bassen, Project Engineer, U.S. Postal Service Laboratory

Abstract

Off-the-shelf and experimental metal detectors were evaluated for the location of "suspect" parcels containing illegal weapons or pipe bombs. Certain techniques proved effective in screening mail, thus cutting down the work load of a hypothetical X-ray inspection system.

A precision magnetometer was used by the author to obtain absolute magnetic measurement data on various handguns and metal objects. A commercial fluxgate gradiometer was then installed about a conveyor belt and used with an automatic data acquisition system. A field test on 2000 parcels showed false alarm rates of 20 percent to 35 percent for this equipment when small pistols were to be always detected.

A contractual effort resulted in the development of a two-axis, active weapon detector with very stable and uniform sensitivity characteristics. A field test similar to the one previously mentioned yielded a false alarm rate of approximately 20 percent to 35 percent when small pistols were to be always detected. While this result was no better than that of the passive detector, less interference from nearby moving objects was observed with the active system. The small aluminum frame and stainless steel pistols which can evade the detection of passive systems also established a basis for choosing active detection techniques.

All work was done under an experimental program by the U.S. Postal Service Research Department. The metal detectors and the X-ray equipment studied have not been, or necessarily will be, operationally used by the Postal Inspection Service.

Introduction

A program was begun in 1969 in the U.S. Postal Service Research Department to develop devices that could be used in the detection of illegal weapons and bombs in the mails. A primary tool for such applications would be an X-ray system which would allow non-destructive parcel examination. In order to reduce the number of "suspect" parcels to be X-rayed, various pre-imaging sensors were considered. Metal weapons detectors were found to be highly promising for such a screening procedure and were evaluated by the U.S. Postal Service Laboratory.

Passive Magnetometer Fundamentals

Because of their low cost and wide availability, fluxgate magnetometers have been widely used by commercial airlines in recent years for anti-hijacking (weapon detection) purposes. A short 3-month feasibility study was carried out with modified commercially available magnetometers to determine their effectiveness as a non-destructive means of examining parcels for illegal handguns, pipe bombs, rifles, and grenades. Fluxgate magnetometers have been successfully used for the measurement of static magnetic fields, such as the earth's magnetic field (terrestrial magnetism). Both the amplitude and orientation of large and small static and slowly varying magnetic fields may be accurately measured with fluxgate magnetometers over the range of several Gauss, to 10^{-5} Gauss (1 Gamma). The earth's field in the Northeastern United States is approximately 0.5 Gauss at an angle of 75° from the horizontal.

Small ferromagnetic objects (iron and steel) perturb the earth's field in their immediate vicinity because of their high permeability. Therefore, when ferromagnetic objects move into the vicinity of a magnetometer, a net change in the earth's field may be measured. A very small, time-varying component of the magnetometer output voltage results when a ferromagnetic object is moved past the magnetometer probe. It can be separated from the large dc voltage proportional to the earth's field by using dc bucking voltage or high pass filtering.

The above measurement of induced magnetism (perturbation of the earth's field) is only one of two quantities simultaneously measured by a passive magnetometer. The second quantity is permanent magnetism. Guns are known to pick up permanent magnetism when fired, since the magnetic domains in steel align with the earth's field when mechanically shocked. Thus, an object's total magnetic moment (the quantity measured by a magnetometer) may be described as:

$$M = I + P \text{ (all are vector quantities)}$$

where:
- M = total magnetic moment
- I = induced magnetism
- P = permanent or residual magnetism due to exposure to magnetic fields or mechanical shock

An object may register a varying amount of total magnetism ranging from zero (if $I = -P$) to quite a large registration ($|P| \gg |I|$). The case of zero registration is of no practical concern, since its probability is minute and has never been experimentally observed in the duration of the survey. If permanent magnetism exists in an object, it is usually a much greater quantity than the induced magnetism of the object.

While their detection zone is omnidirectional, passive magnetometers have a sensitivity to an object which is dependent upon the ferromagnetic object's orientation with respect to the magnetometer axis. Objects perpendicular to this axis are poorly detected. Sensitivity also varies inversely with the cube of the distance from object to magnetometer.

The gradiometer consists of the combination of two magnetometers, oriented along the same axis, and connected so that their voltages are in opposition (Figure 1). The net output of a gradiometer in the presence of a locally uniform magnetic field, such as the earth's field, is zero. By establishing a "common mode" rejection of the earth's field, a gradiometer is capable of directly measuring only the local field gradients (such as those caused by weapons). Large, but distant, ferrous objects which are moving (elevators or carts) are also ignored if they are approximately equidistant to both magnetometers within the gradiometer structure. The gradiometer is therefore much more suitable for the measurement of small gradients in a non-constant magnetic environment, such as a post office, where large steel objects (carts and machinery) are likely to be moved about.

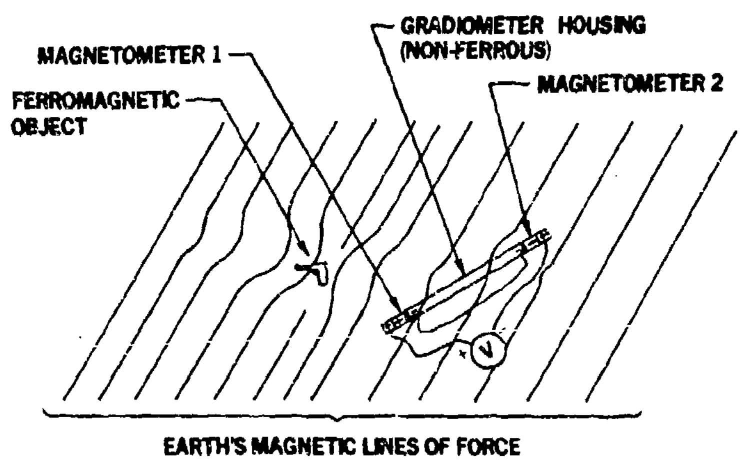


Figure 1. Illustration of a Gradiometer

Passive Magnetometer Experiments

A variable speed conveyor belt, 12 feet long and 17 inches wide, was used to transport various ferromagnetic test objects past a precision magnetometer probe, facilitating the measurement of both conveyor belt background noise and test object signatures. The precision magnetometer was borrowed from the Naval Ordnance Laboratory, White Oak, Maryland. Absolute measurements (in Gammas) of both static and time varying magnetic fields are determined with this device. Since the fluxgate magnetometer is a vector type device, the following components of the magnetic fields under test were measured as shown in Figure 2.

1. Vertical (probe axis pointing up perpendicular to the floor).

2. Longitudinal (probe axis pointing parallel to the line of flow of the conveyor belt).

3. Lateral (probe axis pointing across the belt perpendicular to the line of flow of the conveyor belt and parallel to the floor).

The measurement of magnetic interference from the conveyor belt yielded several important facts as to the magnitude and source of such interference. In the vertical and longitudinal orientations, a periodic magnetic signal was observed on the order of 50 to 300 Gammas. By loosening the belt and manually turning an end roller, the source of the interference was found. Apparently, all the rollers possessed some permanent magnetism. Most belts have two large end rollers, 3 inches to 6 inches in diameter, and several small rollers, 2 inches in diameter, along the length of the belt which maintain the proper tension and alignment of the belt material (rubber-coated canvas). By mounting the magnetometer probe in the lateral direction (probe axis parallel to the roller axis) almost no magnetic interference was observed (less than 5 Gammas peak), except when the steel belt lacing passed the probe. These observations were consistent with those made on a second standard conveyor belt used in the field test.

Various test objects were measured for three probe orientations. A group of simulated gun barrels (3/8-inch-diameter and 1/16-inch-thick wall, steel pipes) were used, along with several handguns, training grenades, and a 2-inch diameter pipe, to provide a set of contraband signature data. All objects were demagnetized with a commercial magnetic tape eraser so as to provide the minimum signature case for all experiments. Before demagnetizing each object, however, measurements were made to provide insight into the amount of permanent magnetism present in the object. Usually, the permanent magnetism was two to 10 times greater than the induced magnetism measured for an object under test. The test barrels (2, 4, and 8 inches in length) proved the most difficult objects to detect since they could be oriented perpendicularly to the magnetometer probe axis, yielding magnetic signatures below the background noise level (when 10 inches or more from the probe). Handguns and the 2-inch-diameter pipes (simulated pipe bombs) were not so unidirectional in their magnetic characteristics and were always measureable at distances of 15 inches or less from the probe. The signal to noise problem was significant at distances of more than 15 inches. This is why the commercial, door-portal weapon detection systems use six or eight magnetometers to search a man passing through the array.

Figure 3 gives typical test data for the above targets. Both noise and target readings were measured, in conjunction with the laboratory conveyor belt, in all three probe orientations. Field test data on the same objects were obtained with the precision magnetometer, using an operational conveyor belt slightly larger than the laboratory conveyor belt. Field test data for each object were within 50 percent of the laboratory data.

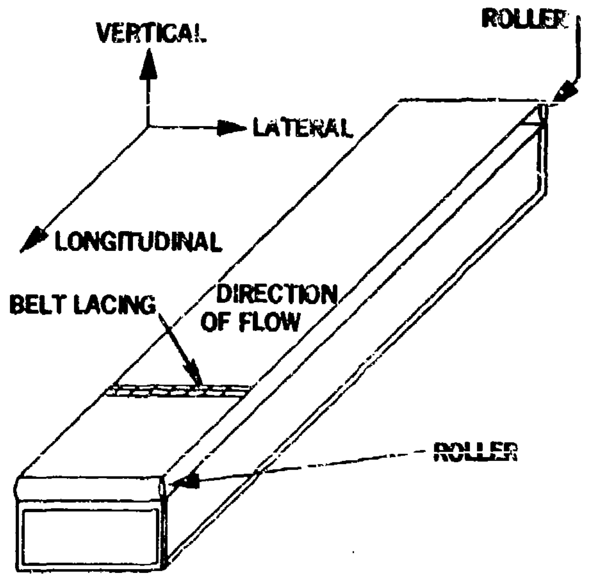
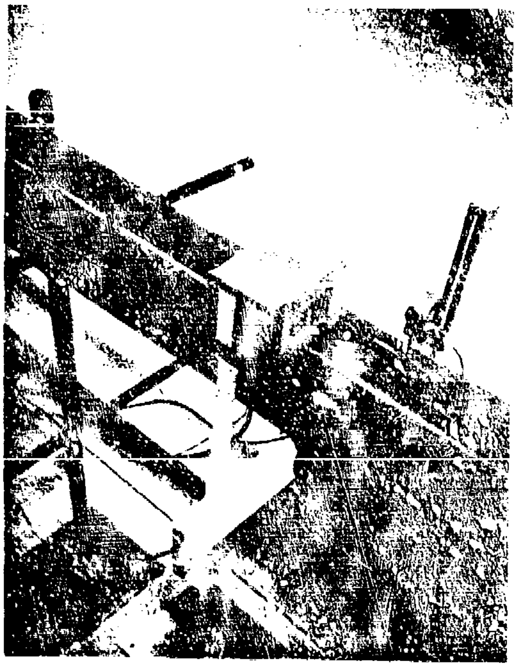


Figure 2. Conveyor Belt Terminology

TEST OBJECT	ORIENTATION	DISTANCE TO PROBE	READING AFTER DEMAGNETIZING
		INCHES	GAMMAS
SIMULATED PISTOL BARREL (4-1/2" LONG)	LONGITUDINAL	6	15
SIMULATED PISTOL BARREL	LATERAL	6	45
SIMULATED PISTOL BARREL	VERTICAL	6 (FROM TOP END)	50
HOPKINS & ALLEN 38 REVOLVER	BARREL LONGITUDINAL	10	35
HOPKINS & ALLEN 38 REVOLVER	BARREL LATERAL	10	30
HOPKINS & ALLEN 38 REVOLVER	BARREL VERTICAL	10 (FROM CENTER OF GUN)	120

Note: Background Noise = 5 gammas P. P.

Figure 3. Precision Magnetometer Data for Test Objects



Note: Black tubes house gradiometer. The white bands at the ends of the rod indicate individual magnetometer locations.

Figure 4. Gradiometer Installed About a Conveyor

Gradiometer Evaluation

A survey of commercially available passive detectors (magnetometers and gradiometers) was made after the above measurements were performed. Magnetometers were evaluated and proved less suitable than gradiometer systems because of their lack of "common mode" magnetic rejection of large, distant, moving objects. The Schonstedt SD 2 system was chosen because of its wide dynamic range (±3 to ±100 Gammas). The unit also had a static field dc balance feature allowing use near large stationary steel objects, such as a conveyor belt. The modified gradiometer system was tested in conjunction with a model G-25 conveyor belt (29 inches wide and 25 feet long) at the field test site. A lateral mounting configuration was used as shown in Figure 4, with one gradiometer placed below the field test conveyor belt and one gradiometer placed above it. Typical test data vs position is shown in Figure 5, with the nine test positions illustrated.

The outer magnetometer of each gradiometer was positioned under or over the centerline of the conveyor belt. The top gradiometer had to be positioned only 15 inches above the belt in order to maintain sufficient sensitivity for all test targets. The resulting sensitivity vs target position was not uniform, but maintained an adequate signal-to-noise ratio for all targets tested. The conveyor noise was approximately 0.5v peak (the output signal was specified by Schonstedt as approximately 0.1v/Gamma), and the smallest signal recorded for a handgun was approximately 1.0v peak. Figure 6 summarizes field test target data, with each target being run through the array in test positions (1) through (9) and run in the vertical, longitudinal, and lateral orientations for each position. Thus 27 pieces of data were recorded for each target, except for the larger objects, which sometimes occupied two test positions in a single run. Test weapons are shown in Figure 7.

The vertical orientation of gradiometers proved unsatisfactory because of high (5v peak) noise introduced by the conveyor belt rollers. The permanent magnetism of the rollers apparently was asymmetric with respect to the gradiometers, otherwise such noise would be eliminated as a "common mode" signal. A longitudinal mounting of the gradiometers was more successful, yielding 1v peak noise (10 Gamma). This was substantially less than the noise measured by the magnetometer under similar orientation, implying that a degree of common mode rejection was occurring in the gradiometer array.

Data Acquisition System for the Gradiometer Field Test

Automatic data acquisition for field tests was accomplished with the following system. A peak detecting, absolute value circuit (Figure 8) was used to obtain the magnitude of the peak of the gradiometer output voltage when a target passed the probe. A photocell-gated

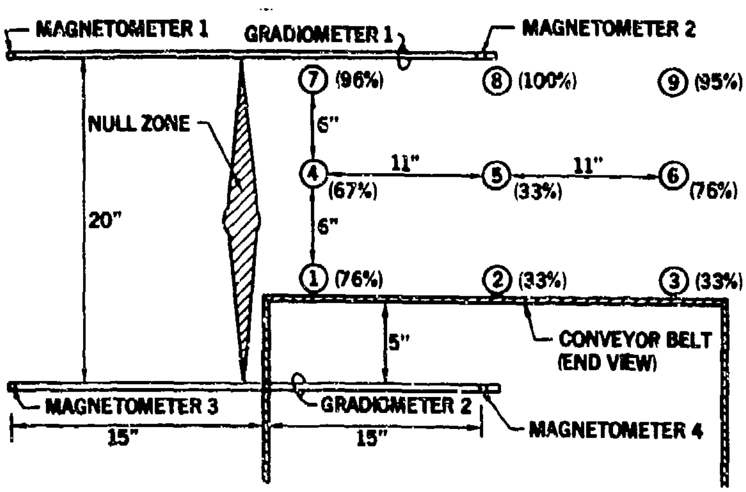


Figure 5. End View of Gradiometer Array Illustrating Nine Test Positions

TEST OBJECT	ORIENTATION	MINIMUM READING	AVERAGE READING
		VOLTS	VOLTS
HOPKINS & ALLEN 38 REVOLVER	BARREL LONGITUDINAL	2.7	6.0
HOPKINS & ALLEN 38 REVOLVER	BARREL VERTICAL	3.5	7.1
HOPKINS & ALLEN 38 REVOLVER	BARREL LATERAL	0.9	3.2
SMITH & WESSON 38 SNUB-NOSE REVOLVER	BARREL LONGITUDINAL	2.1	5.0
SMITH & WESSON 38 SNUB-NOSE REVOLVER	BARREL VERTICAL	4.8	7.5
SMITH & WESSON 38 SNUB-NOSE REVOLVER	BARREL LATERAL	1.4	5.0

NOTES:

1. 1 GAMMA = 0.1 VOLT
2. AVERAGE READING TAKEN ON THE BASIS OF NINE TEST POSITIONS FOR EACH ORIENTATION
3. ALL OBJECTS DEMAGNETIZED BEFORE MEASURING

Note:
Background
Noise = .5v pp

Figure 6a. Gradiometer Data for Test Objects

TEST OBJECT	ORIENTATION	MINIMUM READING	AVERAGE READING
		VOLTS	VOLTS
ASTRA CUB 22 PISTOL	BARREL LONGITUDINAL	1.8	5.9
ASTRA CUB 22 PISTOL	BARREL VERTICAL	4.1	6.8
ASTRA CUB 22 PISTOL	BARREL LATERAL	1.5	4.0
STEEL PIPE 2" O.D. 6" LONG	LONGITUDINAL	1.8	7.3
STEEL PIPE	VERTICAL	3.4	7.7
STEEL PIPE	LATERIAL	1.4	7.2

Figure 6b. Gradiometer Data for Test Objects (continued)

TEST OBJECT	ORIENTATION	MINIMUM READING	AVERAGE READING
		VOLTS	VOLTS
BALLESTER-MOLLINA 45 AUTOMATIC PISTOL	BARREL LONGITUDINAL	1.6	5.3
BALLESTER-MOLLINA 45 AUTOMATIC PISTOL	BARREL VERTICAL	8.8	9.8
BALLESTER-MOLLINA 45 AUTOMATIC PISTOL	BARREL LATERAL	2.4	7.3

NOTES:

1. 1 GAMMA = 0.1 VOLT
2. AVERAGE READING TAKEN ON THE BASIS OF NINE TEST POSITIONS FOR EACH ORIENTATION
3. ALL OBJECTS DEMAGNETIZED BEFORE MEASURING

Figure 6c. Gradiometer Data for Test Objects (continued)

A - Hopkins & Allen .38 Revolver
B - Astra Cub .22 Pistol
C - Ballester-Mollina .45 Automatic Pistol

Note 12-inch ruler at right.

Figure 7. Test Guns--Passive System

digital circuit provided a peak detector "read" signal which allowed the peak detector to monitor the gradiometer output voltage only when any part of the package was within one foot (either side) of the gradiometer probe. The false signal, occurring when the conveyor belt steel lacing passed the probe, was not permitted to be read by the peak detector, since the package under test was never placed near the lacing. After the peak detector "read" signal ended, a digital voltmeter "read" (DVM read) pulse (200m sec) was generated by triggering a "one-shot" with the trailing edge of the peak detector "read" pulse. A peak detector reset pulse, 2 seconds in duration, followed the "DVM read" pulse, being generated by a "one-shot" which was triggered by the trailing edge of the "DVM read" pulse. The peak detector reset pulse activated a relay which then shorted out the peak detector storage capacitor, returning the system to its original zero state. The relay generated no measurable magnetic interference. The peak detector reset pulse also triggered a digital printer which provided a paper printout of the digital voltmeter reading. The system performance sequence is illustrated in Figure 9.

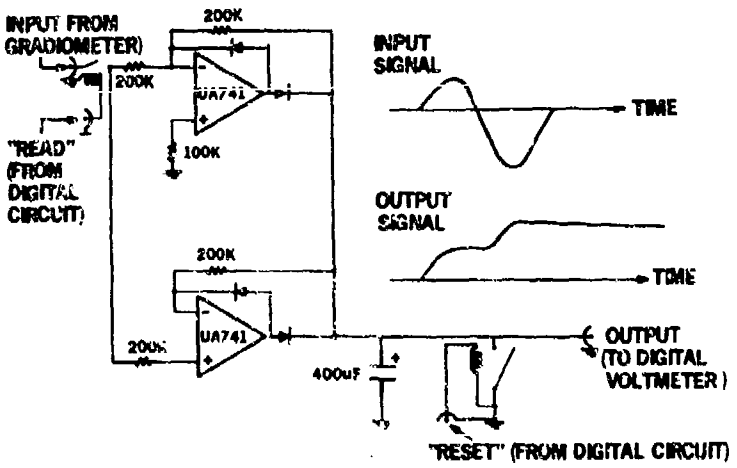


Figure 8. Absolute Value, Peak-Detector Circuit

Gradiometer Field Test on Live Parcels

All incoming mail for Washington, D.C., passes through the V Street Annex. The live parcel field test, in two phases, was held there for 7 days. (Figure 10.) In experiment 1, approximately 400 packages per day were tested for four days. Each day's packages were randomly selected from a specific "district" of the city (suburb, downtown commercial, or industrial). Usually two to four zip code zones comprised a "district". The suburban district chosen was

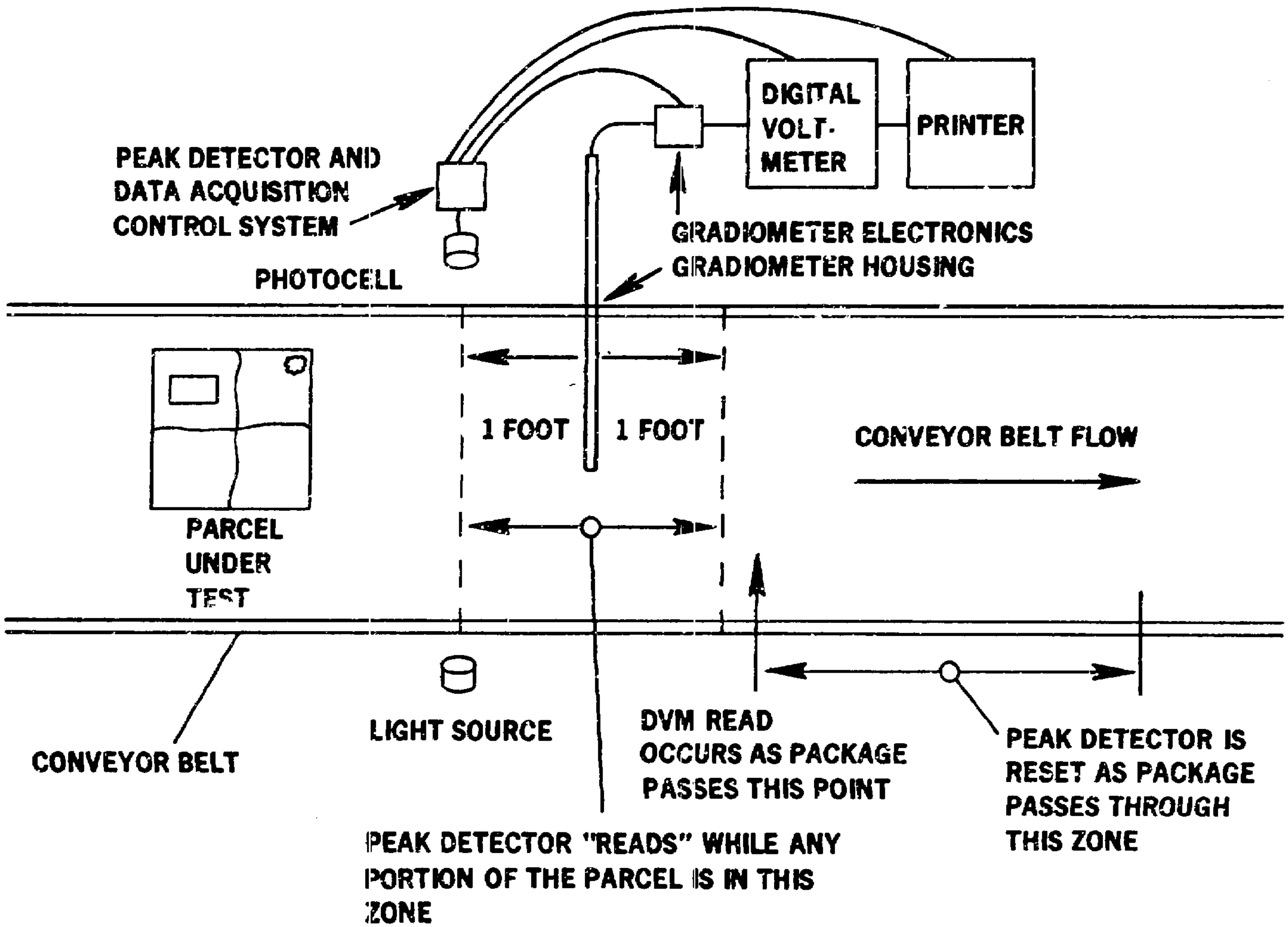


Figure 9. Gradiometer Data Acquisition System

Chevy Chase (20014 and 20034), which included many private residences and a large shopping center (Montgomery Mall), as well as the Naval Medical Laboratory. The downtown commercial district (20006, 20024, 20036) included the White House, Dupont Circle and a Southwest Washington apartment complex. Retail stores predominated this district's mail recipients. An industrial and warehouse district, New York Avenue, N.E., and Bladensburg Road (20002, 20018, 20017), included manufacturing, machine shops, and residential dwellings. In all zones, many small parcels (2" x 12" x 12"), about 25 percent of the total mail, were observed over the entire test period. Most of these appeared to be printed matter, hence, non-magnetic. Large staples and steel reinforcing bands were rarely observed during the test; therefore, they did not appreciably affect the overall alarm rate.

Experiment 2 involved inspecting each parcel twice, the first involving selection identical to the method used in Phase 1, with the second run being done with the parcel rotated 90° on the belt so as to provide a two-dimensional search. This served to simulate a two-axis (longitudinal and lateral) gradiometer array. With such an array, the spread of signature amplitudes would be considerably reduced for weapons in various orientations. A reduced alarm rate would therefore result from the improved uniformity of sensitivity.

Figure 10. Passive System Field Test

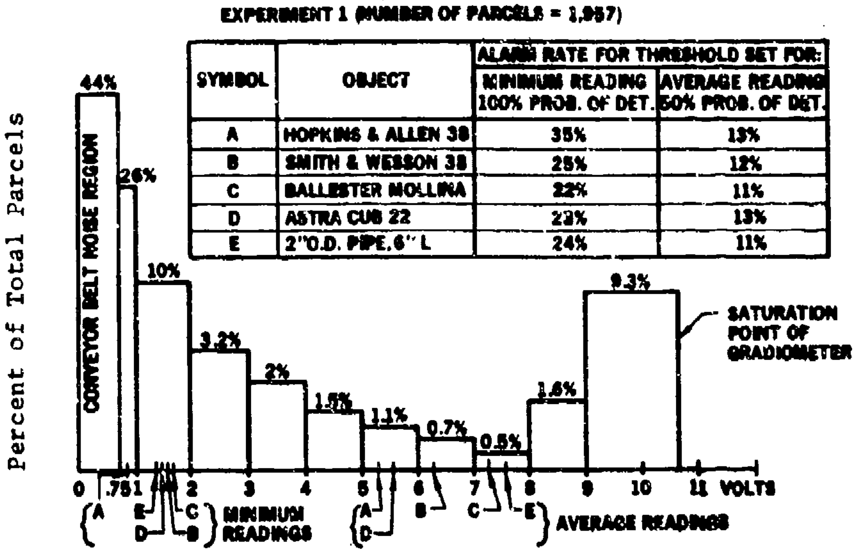
Gradiometer Field Test Data Analysis

Field test data were computer-analyzed with a ranking program which rearranged the data (gradiometer peak output voltage per package) in increasing order. Each day's data were ranked separately (both Experiment 1, using the single-axis measurement, and Experiment 2, the two-axis measurement). In addition, all data were ranked in a single listing (a total of 1,957 parcels for Experiment 1, and 555 parcels for Experiment 2). As each day's parcels were taken from a specific geographical area of the city, magnetic content vs area could be determined.

Results are shown in Figure 11 for all data taken in Experiment 1, and in Figure 12 for all data taken in Experiment 2. When compared with the individual daily data, no disagreement with the combined total ranking ever exceeded a few percent at any point in the ranking. That is, no significant difference in the magnetic statistics was noticeable for the various areas of the city.

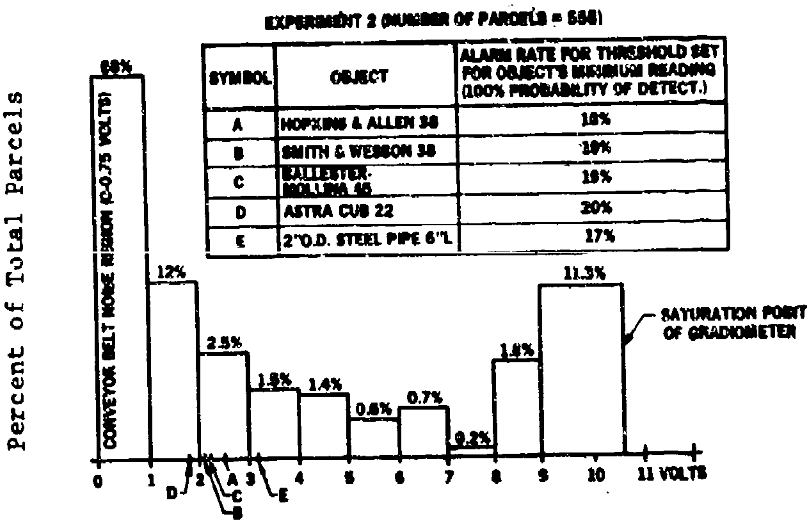
Definite statistical alarm rates were established by comparing the test data from parcels whose contents were unknown with the data obtained for all test objects (Figure 6). A 100 percent probability of detection threshold was chosen by picking the minimum reading from each of the test objects and finding this level in the ranked experimental data. The 50 percent probability of detection was based upon the smallest average reading of the data in Figure 6. This level would represent a 50 percent probability of detecting a specific weapon's signature. As shown in Figure 11, 22 to 35 percent of all parcels tested in Experiment 1 would have registered an alarm if a single small gun or pipe was to be definitely detected, regardless of its location orientation in the parcel. By raising the threshold so that there was a 50 percent certainty of detecting any small single weapon in a parcel, only 11 to 13 percent of the parcels would register an alarm. For larger guns and rifles, or a parcel containing more than one gun, a much lower alarm rate would result, since the alarm threshold voltage could be raised considerably.

Experiment 2 was done in order to find the effect of a two-axis longitudinal and lateral measurement on the alarm rate. Test object data were studied, and the greatest reading for a single object data was studied and the greatest reading for a single position on the belt was recorded from the two orientations (Figure 13). This was done because a gun laterally oriented in a parcel during Experiment 2 would be reoriented longitudinally when the package was run through the gradiometer array a second time (rotated 90° from its original position during its first run). This cut down the alarm rate to 17 to 20 percent (Figure 12) for a 100 percent probability of detection. It is realized that guns oriented in between the exact longitudinal or lateral directions would give somewhat different readings, but these would be close to those determined for the three principal axes. The use of a two-axis gradiometer array would allow the same lower alarm rate to occur as in Experiment 2, with each package run through the array only once. In all the data analyses, live mail was assumed to contain much less than 1 percent true alarms. Therefore, all alarms were considered false.



SYMBOL	OBJECT	ALARM RATE FOR THRESHOLD SET FOR: MINIMUM READING 100% PROB. OF DET.	AVERAGE READING 50% PROB. OF DET.
A	HOPKINS & ALLEN 38	35%	13%
B	SMITH & WESSON 38	25%	12%
C	BALLESTER MOLLINA	22%	11%
D	ASTRA CUB 22	23%	13%
E	2"O.D. PIPE, 6" L	24%	11%

Figure 11. Measured Parcel Magnetic Content Distribution--Experiment 1



SYMBOL	OBJECT	ALARM RATE FOR THRESHOLD SET FOR OBJECT'S MINIMUM READING (100% PROBABILITY OF DETECT.)
A	HOPKINS & ALLEN 38	16%
B	SMITH & WESSON 38	19%
C	BALLESTER-MOLLINA 45	19%
D	ASTRA CUB 22	20%
E	2"O.D. STEEL PIPE 6"L	17%

Figure 12a. Two-Axis Measured Parcel Magnetic Content Distribution--Experiment 2

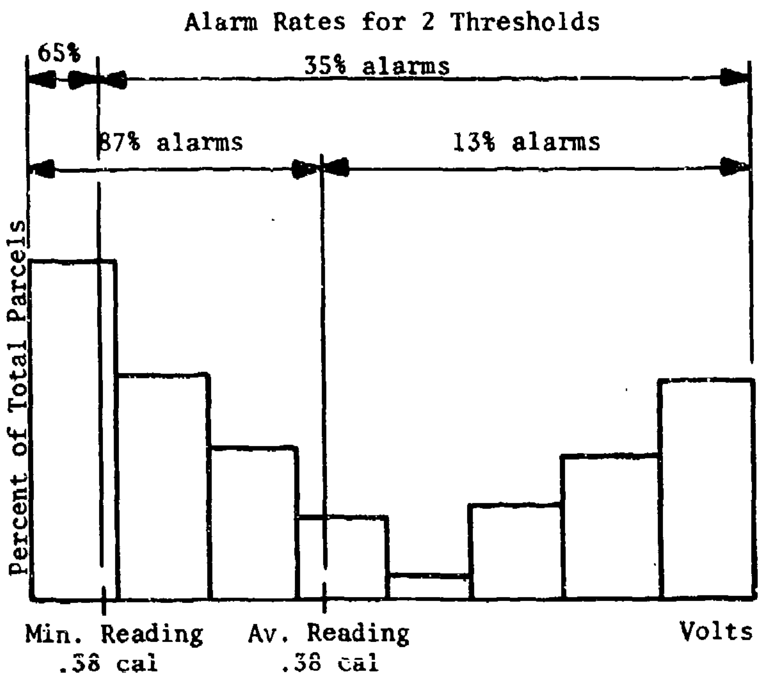


Figure 12b. Interpretation of Magnetic Content Histogram

TEST OBJECT	ORIENTATION	MINIMUM READING
		VOLTS
HOPKINS & ALLEN 38 REVOLVER	VERTICAL	3.5
	HORIZONTAL	2.7
SMITH & WESSON 38 SNUBNOSE REVOLVER	VERTICAL	4.6
	HORIZONTAL	2.1
BALLESTER MOLLINA AUTOMATIC PISTOL	VERTICAL	8.9
	HORIZONTAL	2.1
ASTRA CUB 22 PISTOL	VERTICAL	4.1
	HORIZONTAL	1.8
STEEL PIPE 2"O.D.×6"LONG	VERTICAL	3.4
	HORIZONTAL	3.2

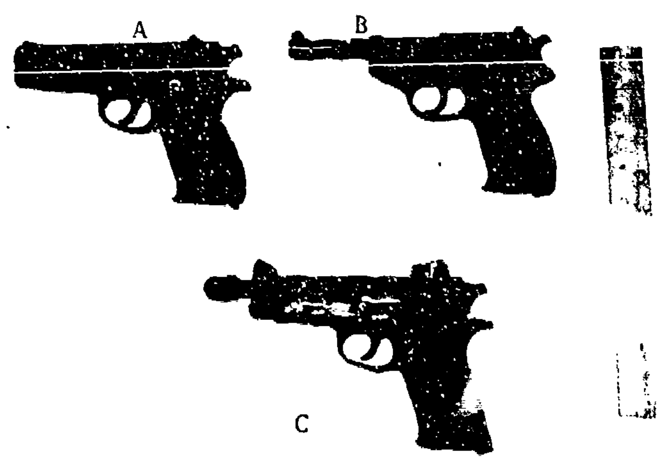
NOTE : HORIZONTAL = COMBINATION OF LONGITUDINAL AND LATERAL DATA FOR EACH POSITION.

Figure 13. Gradiometer Data (Two-Axis) For Test Objects

Other Experiments With Gradiometers

Magnetic interference measurements were made with the gradiometer system installed about a conveyor belt. A steel cart, 5 feet long by 2-1/2 feet wide by 3 feet high, was pushed into the vicinity of the conveyor belt. At a distance of approximately 10 feet from the gradiometer array, a 0.5 to 1.0 volt peak reading was observed for several directions of cart travel. Therefore, a 15-foot radius "zone of clearance" should be maintained about the gradiometer array.

A group of "non-magnetic guns" was tested to determine their detectability with passive magnetometers. These guns, borrowed from NOL, White Oak, were military pistols with aluminum or stainless steel frames. It was observed, however, that all of these guns had ferromagnetic barrels and miscellaneous hardware. The stainless steel was found to be of the magnetic variety (some stainless steel is not ferromagnetic). The guns shown in Figure 14 were run through the gradiometer array in three orientations. The gradiometer readings were compared with a small standard pistol, run through the array in the same positions and orientations. All guns, except the Smith and Wesson Model 39 Aluminum frame pistol, yielded higher readings than the standard gun in every orientation. The Model 39 yielded a low reading (7 Gammas) as opposed to the standard gun's reading (40 Gammas) in the longitudinal orientation. This was due to the orthogonal orientation of the barrel with respect to the gradiometer probe. A second gradiometer, mounted in the longitudinal direction, would provide reliable detection of the aluminum frame gun for all gun orientations. After the completion of the passive magnetometer study, a small, non-magnetic stainless steel pistol was discovered which was undetectable. This weapon was (Anderson Arms .25 caliber automatic) detectable in the "advanced weapons detection program," which is described later in this paper.



A - Smith & Wesson Aluminum Frame Pistol
B - Walther P-38 Aluminum Frame Pistol
C - Smith & Wesson Stainless Steel Pistol

Figure 14. "Non-Magnetic" Guns Tested

Conclusions of The Passive Magnetometer Study

The fluxgate magnetometer (in the form of a gradiometer array) provides a readily available, simple, and moderately priced means for weapons detection. It is sensitive only to ferromagnetic metals, which eliminates a portion of the potential false alarms from non-ferrous metal objects commonly shipped through the mails. Because of the vector-determining nature of the fluxgate magnetometer, it would be advisable to use a multi-axis gradiometer system--one which would detect both horizontal and vertical components of the earth's field. This would provide a more uniform sensitivity for guns in all orientations.

The major shortcoming of the passive magnetometer is its undesirable sensitivity to an object's permanent magnetism, which is an unpredictable quantity. The meaningful measure of an object's ferromagnetic mass (induced magnetism) is overwhelmed, in many instances, by this permanent magnetism. This, in turn, increases the passive magnetometer's false alarm rate because very small objects possessing a large amount of permanent magnetism are "seen" as large ferromagnetic objects.

If a static magnetic field is generated so as to uniformly cover the area under surveillance, certain advantages can be realized. If this field is large, compared to the earth's field, a better signal-to-noise ratio can be obtained with magnetometers, and interference from large, distant objects is reduced. The effect of an object's residual magnetism can be diminished, compared to its induced magnetism. Therefore, more uniformity from similar guns with various amounts of residual magnetism can be achieved in this type of system. Field strengths must be low enough so as to cause no erasure of magnetic tapes.

Field test data taken on approximately 2000 parcels indicated that 22 to 35 percent of the parcels inspected with a commercially available gradiometer array yielded magnetic signatures equal to that of the smallest handgun tested. This corresponds to a 100 percent probability of detection of a single gun or pipe-bomb in any orientation, and in any position within a 30-inch-wide by 15-inch-high package zone. For a 50 percent probability of detection, the alarm threshold could be raised so that only 11 to 13 percent of the parcels tested would yield an alarm. It was found that the gradiometer array used did not provide uniform sensitivity over the entire package zone. A better coverage (as would be provided in the recommended system shown in Figure 15) would significantly reduce false alarms, since a uniform coverage of the package zone would allow a higher alarm threshold to be used.

A two-axis measurement on 555 parcels reduced the alarm rate slightly (17 to 20 percent) for a 100 percent probability of detecting

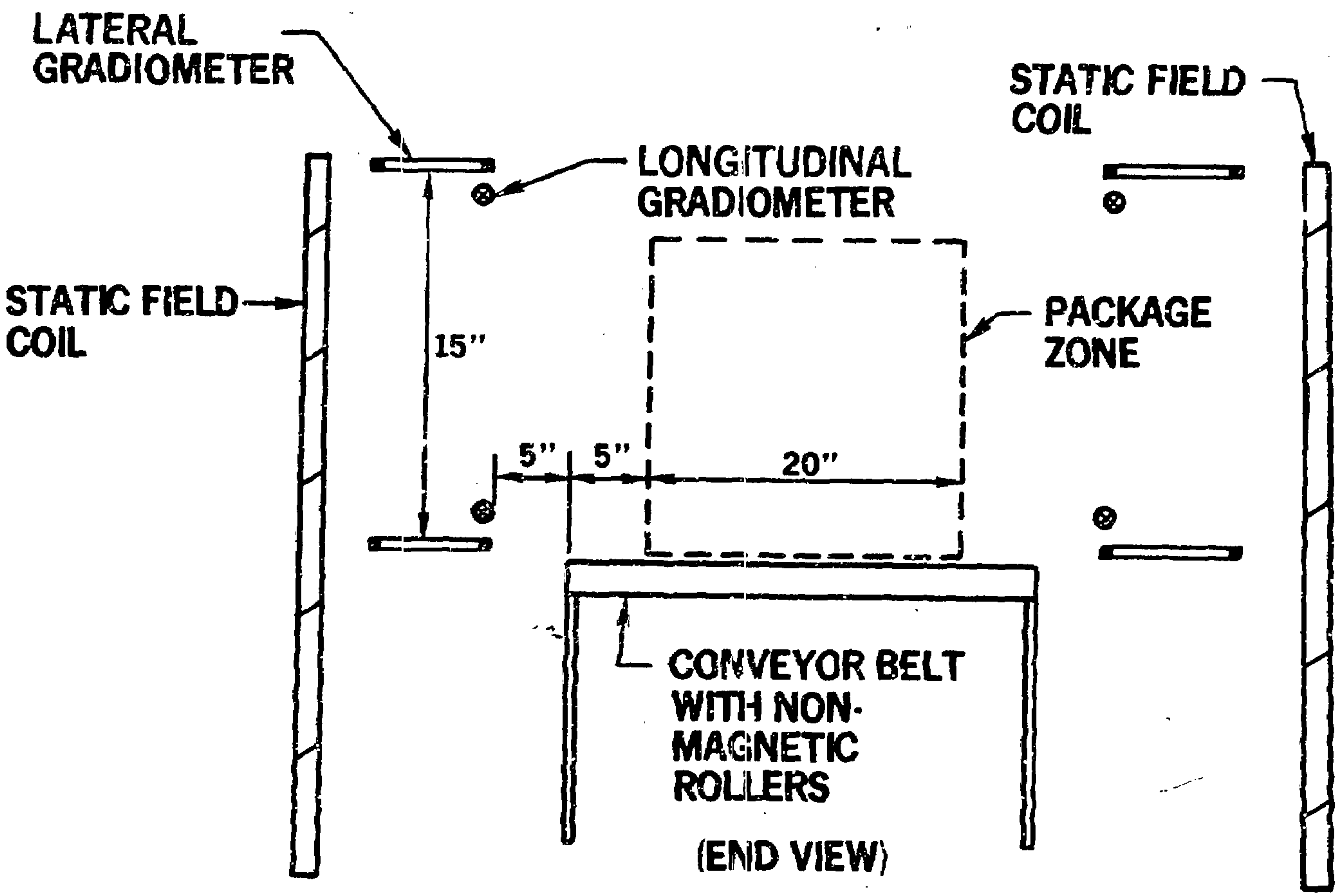


Figure 15. Recommended Gradiometer Array for Parcel Inspection

even the smallest weapon used in the study. The two-axis gradiometer array is, therefore, considered desirable in further reducing the alarm rate.

A 15-foot radius zone of clearance was found to provide immunity from interference generated by moving carts and adjacent conveyor belts. No means of shielding such interference was found.

Recommendations for Passive Magnetometer/Gradiometer Applications

The recommended system shown in Figure 15 is used to provide uniformity of sensitivity regardless of the object's orientation or spatial position within the package zone. The use of four two-axis gradiometers is proposed in order to establish uniform sensitivity by keeping the sensor-to-target distance relatively constant within the array. Ideally, the sensors would be placed at a great distance from the package zone, so that all possible weapon positions within the zone would be approximately the same distance from the sensor. This great distance is impractical, since the sensitivity of the fluxgate gradiometer is insufficient for detecting guns at a distance of more than a few feet. Also, other large moving ferromagnetic objects would cause an appreciable interference problem for very large sensor-to-package distances because of the required high sensitivity. The recommended system (Figure 15) therefore represents a situation in which the package-to-sensor separation has been optimized on the basis of required sensitivity in the presence of typical magnetic interference (carts and conveyors). A static magnetic field would be used to reduce residual magnetic effects from objects under test. The eight gradiometers would be approximately 6-1/2 inches long, and would share as much common electronics as possible. This type of gradiometer is currently available for portable, personnel search applications by several firms. Probably two separate electronics systems, including threshold circuitry, would be used, one for the longitudinal array and one for the lateral array. An OR gate could combine both threshold alarm outputs, thus providing a single system alarm. The system could be used in conjunction with a conveyor belt whose moving parts would contain as little ferromagnetic material as possible. Non-magnetic rollers would definitely be required in the conveyor belt.

Active Weapons Detection System: Background

Upon the completion of the in-house passive magnetometer study, certain facts regarding parcel inspection for metallic weapons had been established. Typical groups of parcels contained no more than 30 to 35 percent potential alarm sources as a worst case. It would be necessary to reduce this alarm rate to 10 to 20 percent to provide justification for the use of such systems. Sensitivity variations due to a weapon's orientation and position within a parcel should be minimized. A reduction in the sensitivity to interference sources (machinery, carts) would be needed for an operational system. Finally, a capability for the detection of non-ferrous weapons should be incorporated into any future prototypes.

Active metal detectors had recently been developed by various R&D sources for door-portal, personnel search applications. These systems utilized the principles of mine and coin detectors. A pair of coils was physically mounted on the same housing. One coil transmitted a low frequency magnetic field. The other coil (receive) was positioned so that the transmitted field was geometrically balanced out or nulled in a free space situation. When metal was introduced into the vicinity of this coil pair, the magnetic field was disturbed, and an unbalanced condition produced a net difference signal in the receiver. Furthermore, the metal's conductivity (and in the case of a ferrous metal, its permeability) affected the phase of the received signal with respect to the transmitter phase. Therefore, active systems provided metal composition identification capabilities which could possibly discriminate against non-weapons. Also, their sensitivity could be made uniform over any given area by adjusting transmit and receive field patterns.

Active systems provide a sensitivity to metal objects which varies with the sixth power of the distance from the coil pair (as opposed to the third power relationship of passive magnetometers). This means that the degree of interference from metal objects outside the parcel zone drops very rapidly with distance, so that only a small zone of clearance would be needed in a field-installed active weapons detector.

A contract was awarded to Southwest Research Institute (SWRI), San Antonio, Texas, to modify an active weapons detection system which had been developed for personnel inspection. The active system developed for the Postal Service used a specially constructed conveyor belt with a long center section containing no metal. Nylon bolts and wood glue were used to fasten this section together. In this section, two coil sets were installed (Figure 16) to provide a two-axis search of the parcel. A lateral axis coil pair was installed at the input end of the conveyor. A transmitting coil was placed on one side of the conveyor and a receive coil on the opposite side of the belt. A second longitudinal coil set was mounted further down the belt. For this coaxial coil set, a single wooden form surrounded the belt, with parcels passing through its center. The coil set contained transmitting, receive, and nulling coils. The coils were designed via a computer program to provide highly uniform sensitivity to a metallic object in any position within the parcel zone (20 inches wide by 20 inches high, with the bottom of the zone being the belt surface). The computer program proved very accurate, since the actual coils provided a uniformity in the parcel zone such that a steel sphere yielded a receiver output which varied no more than 1.75:1 from the least sensitive spot to the most sensitive spot in either coil set's parcel zone, and 2:1 for the combination of both coil sets.

An operating frequency was chosen on the basis of experiments with an SWRI breadboard. At 90 Hz, the sensitivity to non-ferrous, pistol-sized objects was below the system's background noise level. Small pistols with primarily ferromagnetic parts were easily detected. At 391 Hz, the ratio of sensitivities to steel vs aluminum objects with identical dimensions was approximately 3:1. Higher frequencies would equalize the sensitivities to ferrous or non-ferrous objects. On the basis of these breadboard tests, a prototype operating frequency of 391 Hz was chosen in an effort to discriminate against potential false alarms from non-ferrous objects, yet maintain some sensitivity for non-ferrous weapons. This frequency could be raised or lowered, pending the results of field tests.

The SWRI system processed the received signal into In-Phase (I) and Quadrature (Q) output channels. A phase angle and the magnitude of a metal object's receiver signature could be computed from I and Q channel data. A circuit to provide a magnitude (vector sum of I and Q) output was provided in the SWRI prototype. The magnitude signal was in proportion to the size of a detected metal object. Phase information was not provided as a system output, but was calculated from the I and Q channel output data. Phase angles of approximately 155° to 175° were obtained for aluminum and other non-ferrous objects, and angles of approximately 240° to 260° were obtained for iron objects. Other phase angle values for other items containing combinations of ferrous and non-ferrous objects, or low-conductivity ferrous metals such as ferrites, were obtained.

Field strengths of the transmitter coils were similar to that of the earth's field (0.5 to 1 Gauss flux density). Therefore, no magnetic tape erasure problem was likely. Actual experiments with the final prototype demonstrated that no tape erasure occurred even with tapes held against the transmitter coil.

Active System Laboratory Tests

Sensitivity tests with simple metal objects were performed with the final prototype. As previously mentioned, a steel sphere was tested in nine positions in the 20-inch by 20-inch parcel zone. A 2:1 total variation existed between the least sensitive position and the most sensitive position in the parcel zone of both coil sets. Phase angles varied only a few degrees over the same conditions. A series of tests performed on a .38 caliber pistol provided a worst case sensitivity spread of 2.75:1 for both coils and for longitudinal, lateral, and vertical barrel orientations. This was a great improvement over the passive gradiometer tests, where the same conditions yielded approximately a 10:1 variation in sensitivities.

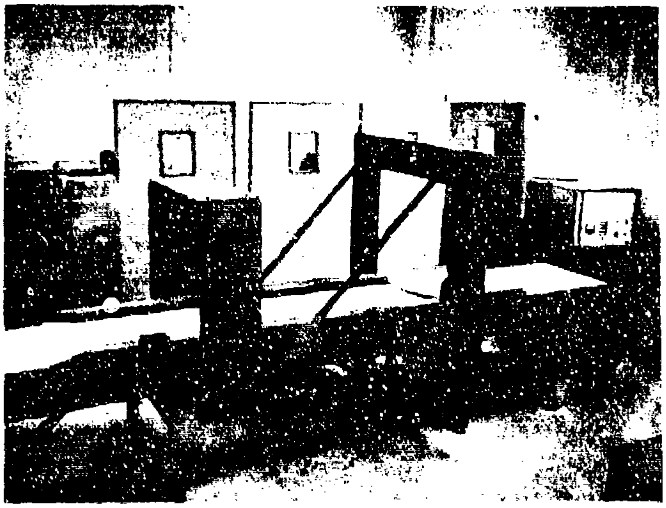


Figure 16. SWRI Active System

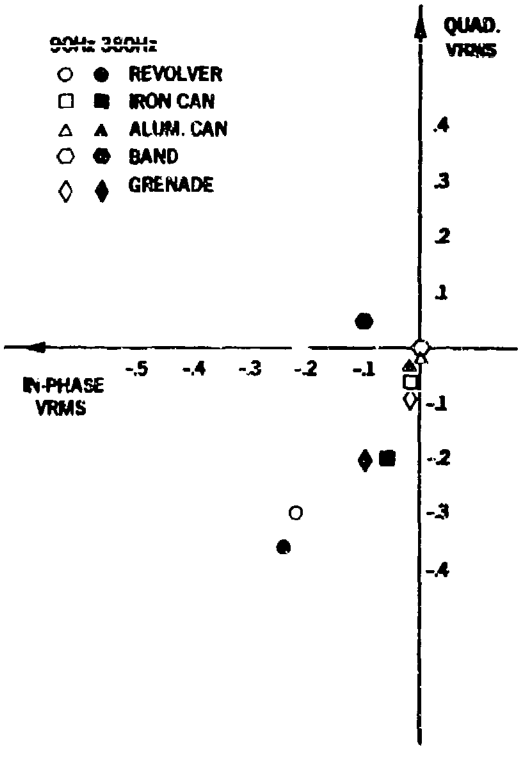


Figure 17. Typical Data at Two Operating Frequencies

Magnitudes and phase angles were computed for various test objects. In Figure 17, typical test objects are shown in a polar plot, as measured by an SWRI breadboard system early in the program. The significance of phase angle as an aid to discrimination can be seen by noting the aluminum can's angular position relative to a steel revolver or grenade. Phase information, however, is a composite quantity relating the electromagnetic properties of all samples within the parcel zone. Thus, a mixture of steel and aluminum, such as an aluminum frame gun, was found to possess no single specific phase angle when it was measured in various orientations in the parcel zone. For a longitudinal barrel orientation, a 156° phase angle was measured with the lateral coil set, while a 230° phase angle was measured with a lateral orientation in the same coil set. The first angle (156°) is characteristic of aluminum. This is due to large eddy current flow in the aluminum frame. The second angle is characteristic of ferrous metals. Hence, phase discrimination is prone to error. A ferrous gun in a parcel with many non-ferrous items can be effectively "camouflaged" if too narrow a band of phase limits is imposed in the detector.

Magnitude measurements of 10 handguns varied from 0.4 to 14mV, at the system's output. The 0.4mV reading was obtained for an all-stainless-steel, .25 caliber automatic pistol (American Firearms), which was totally non-magnetic, except for the cartridge clip and a small steel pin which ran down the body of the weapon. This weapon was found to be virtually undetectable by a gradiometer, when demagnetized.

Non-weapons, such as household appliances and metal bands around a parcel, generally fell within the phase and magnitude ranges of small weapons. A few items, such as field glasses, could be phase discriminated without affecting the detection of any weapon studied.

Figures 18 through 21 illustrate SWRI laboratory tests.

Field Tests of the Active System

A 6-day field test was performed at the San Antonio, Texas, parcel post substation with a total of 1963 parcels being tested. Four "districts" were selected: downtown business, industrial, residential, and military bases. Data acquisition was performed with an A/D converter and paper tape punch which sampled both I and Q channels at a 5-sample/second rate. The sampling period began when a parcel broke a photocell several feet ahead of the first (lateral) coil set. Fifty samples were taken of each channel such that the sampling ended when the parcel had completely passed out of the second (longitudinal) coil set's zone of sensitivity.

Parcels were sorted into large and small categories with a "small" parcel being less than 12 inches by 12 inches by 2 inches in

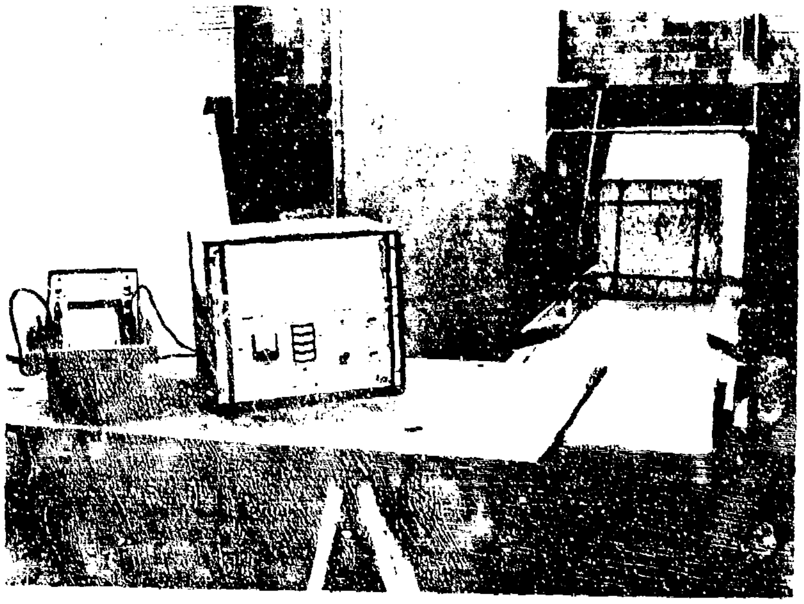
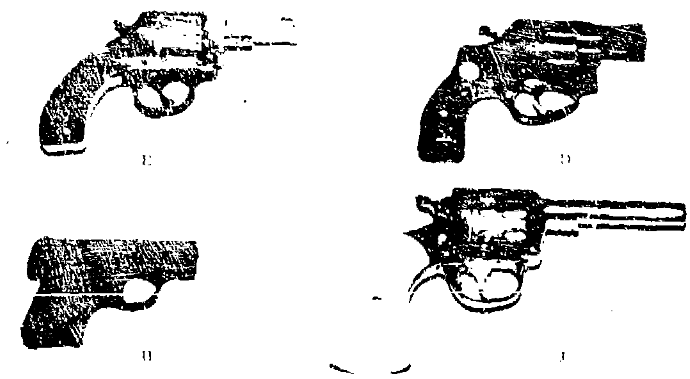


Figure 18. Laboratory Tests at SWRI on Banded Box



E - .38 Calibre Revolver
H - .25 Calibre Automatic

D - .32 Calibre Revolver
J - .22 Calibre Revolver

Figure 19. Ferrous Handguns

- A - .22 Calibre Aluminum Frame
- B - American Firearms .25 Calibre Stainless Steel
- C - .38 Calibre Aluminum Frame
- F - .38 Calibre Derringer Aluminum Frame
- G - .25 Calibre Aluminum Frame
- I - .22 Calibre Aluminum Frame

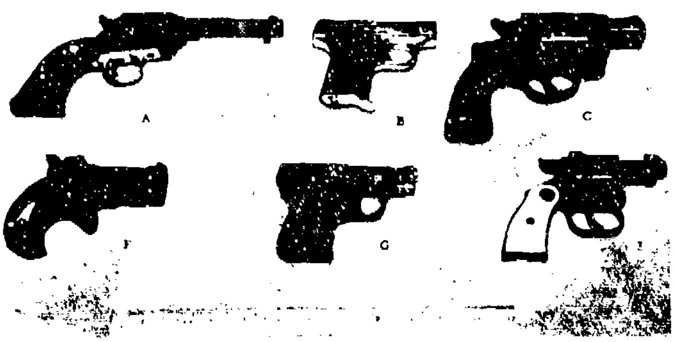


Figure 20. Handguns With Non-Ferrous Frames

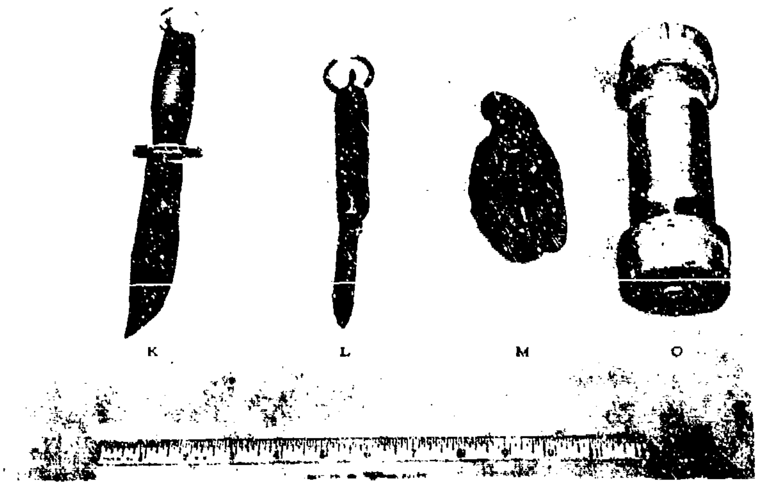


Figure 21. Other Test Weapons

size. A code was entered on the paper tape automatically for each parcel signature indicating the size via a switch setting on the data acquisition system.

At the field test site, interference measurements using actual mail carts indicated that a 4-foot radius zone of clearance was required to eliminate the detection of a weapon-sized signature from a moving mail cart.

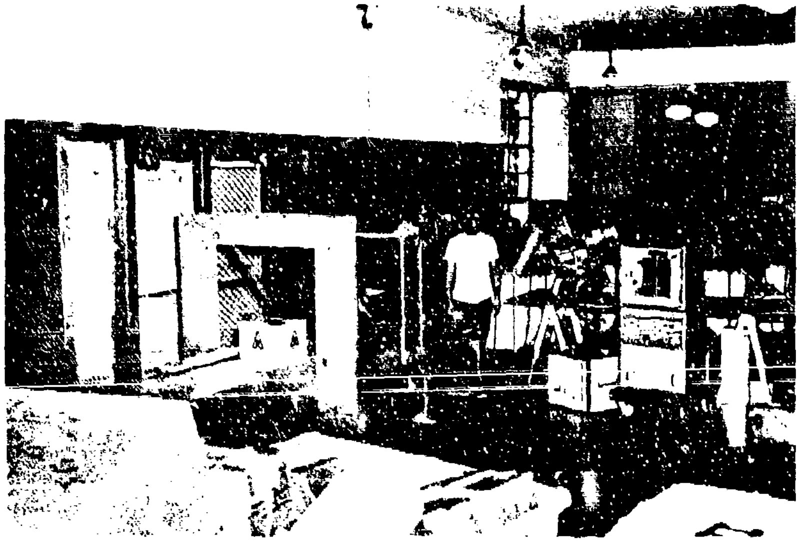


Figure 22. Active System Field Test

Field Test Data Analysis

Two formats were prepared for the field test data via a digital computer and plotter. A polar plot of data points on an "In-Phase-Quadrature Diagram" (Figure 23) indicated grouping densities of parcel data. Objects in the non-weapon phase range could quickly be observed and the metallic composition distribution could be easily understood. Generally, the majority of parcels had either a very low magnitude (clustered about the intersection of the I and Q axes) or were grouped in the ferrous (250° to 270°) range.

A second format used (Figure 24) was the alarm rate vs magnitude plot. Weapon peak signature magnitudes were placed as references along the magnitude (horizontal) axis. Weapon B was the small .25

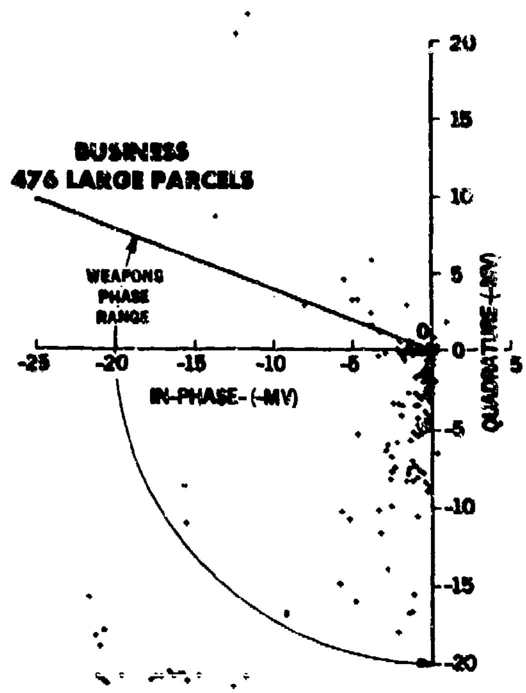


Figure 23. In-Phase, Quadrature Plane Plot for Large Business Parcels

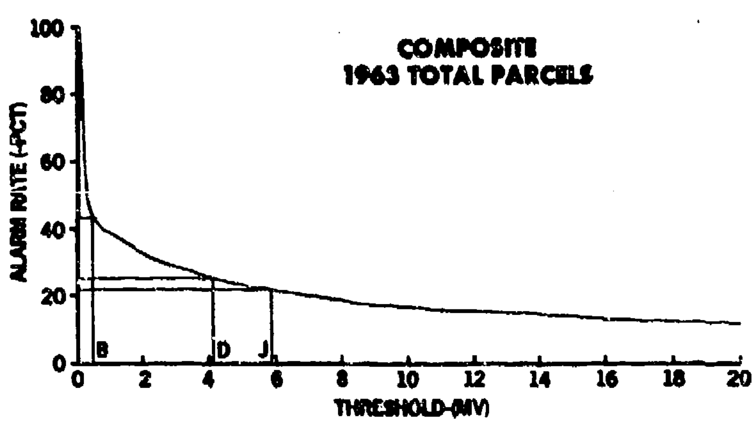


Figure 24. Alarm Rate Plot for Composite Parcels

caliber stainless steel automatic. Weapon D was a snub-nosed, ferrous .38 caliber revolver. Weapon J was a long-barreled ferrous revolver. The alarm rate was found to drop rapidly to approximately 30 percent for a magnitude comparable to a small revolver (J), then to level off at 15 to 20 percent for higher magnitudes. Regardless of the magnitude level, alarm rates never dropped significantly below 15 percent.

By observing the polar plot of the data, some improvement in alarm rate reduction could be seen if phase discrimination was used. This is illustrated by the moderate number of parcels whose magnitude (radius from the intersection of axes) is large, but whose phase lies outside of the weapons range. A third analysis was then run on data with parcels excluded, if their phase was not in the weapons range. A decrease in alarm rate was noted (Figure 25). For example, with objects equal to, or larger than, small revolver "D" the alarm rate for all parcels was reduced from approximately 25 to 20 percent with phase discrimination. This phase discrimination would still allow all weapons to be detected, both non-ferrous and ferrous.

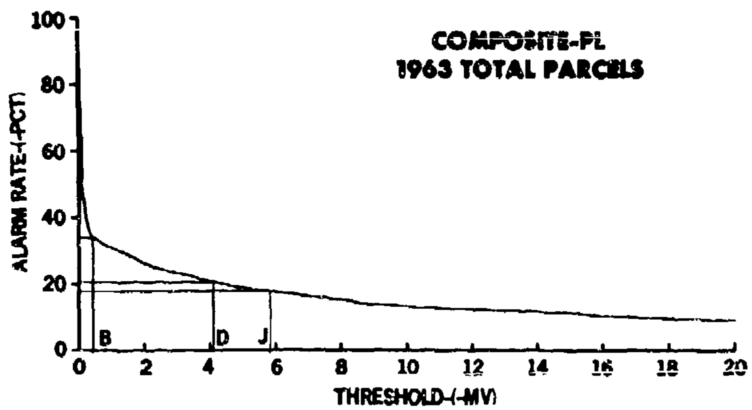


Figure 25. Alarm Rate Plot for Phase Limited Composite Parcels

Conclusions of the Active System Study

In general, laboratory tests yielded anticipated results. Highly uniform detection of metal objects, regardless of their orientation or position within the parcel zone, was achieved. Discrimination against metallic objects that were not weapons would be strictly based on the object's size rather than its composition, if a 100 percent certainty of weapon detection was to be achieved. Phase discrimination techniques could provide lower alarm rates, but at the risk of some uncertainty in detecting weapons mixed in a parcel with other non-ferrous objects.

Alarm rates on typical parcels would fall into the 25 percent range for 100 percent certainty of detecting standard pistols on a magnitude only basis. Miniature, non-ferrous weapons could be detected with 100 percent certainty if a 35 to 45 percent alarm rate could be tolerated. With phase discrimination used conservatively, so that little chance for camouflaging a weapon existed, a 35 percent alarm rate would exist for thresholding set to detect miniature, non-ferrous weapons. A 20 percent alarm rate would result if phase discrimination were used and standard pistols were to be definitely detected.

The detection of non-ferrous weapons, a lower alarm rate, and the reduced sensitivity to interference from moving metallic objects indicate the superiority of active techniques over passive gradiometers.

References

1. Hine, A., "Magnetic Compasses and Magnetometers." Adam Hilger Ltd., London

2. Bassen, H., "An Evaluation of Magnetometers for the Detection of Illegal Weapons in the Mails," August 1971. Postal Service Laboratory Report No. 71-2.

3. Sturdivant, V. R., "Advanced Weapons Detection System," Final Technical Report, March 1972. U.S. Postal Service Contract 72-1-00202. Southwest Research Institute, San Antonio, Texas.

Acknowledgements

The author wishes to thank the following individuals for their assistance in the Weapons Detection Program: Mr. Stabnow and Mr. Peizer of the Naval Ordnance Laboratory, White Oak, Maryland, for their assistance in the passive magnetometer evaluation; Mr. N. Mogan and Mr. J. Wallen of U.S. Army MERDC for guidance on active weapons detection systems.

The technical work on the USPS active system was performed at Southwest Research Institute under the leadership of Mr. V. Sturdivant.

AIRLINE BAGGAGE WEAPON INSPECTION

By: Arthur Beier, Federal Aviation Administration

FAA, like many other government agencies, has an urgent need for devices capable of detecting weapons in packages. Specifically, there is a need to check for weapons in about 200 million pieces of baggage (including briefcases and purses) that are hand-carried aboard airlines every year. In our case, we are mainly interested in .22 caliber and larger handguns, and large knives, since most of the airline hijackings have been accomplished with these kinds of weapons. Detection of both ferrous and non-ferrous metals is essential to a successful program.

A test of three metal weapon-detectors conducted at Dulles Airport last year highlighted the problem and indicated the particular requirements of the FAA. The test covered the evaluation of three commercial metal detectors, ranging from the cheapest passive-type unit to the most sophisticated weapon detector available. About 2,000 passengers and their baggage were checked in this effort. Our objective was a 90 percent weapon detection capability for handguns, with no more than 25 percent false alarms. As far as we were concerned, false alarms meant all alarms on non-weapon carrying passengers, regardless of the total amount of non-weapon metal carried. As the test progressed, it soon became evident that a 90 percent detection capability could not be maintained. An unbelievable number and assortment of metal objects in women's purses and metal frames of men's attache cases caused the false alarm rate to soar above the 25 percent level mentioned above. On the other hand, the false alarm rate for people without hand-carried baggage was considered acceptable on the best unit tested, since it yielded less than 10 percent false alarms and a weapon detection capability in excess of 90 percent.

In addition to the units tested above, several other options remained open to us in our attempts to develop an effective FAA program for detecting weapons in hand-carried baggage. Among these were imaging X-ray units, specially designed electromagnetic field devices, and the application of new technologies. Three commercially available X-ray devices were tested and were found to have a high detection capability. However, use of these devices, which requires human operator interpretation of the image, is considered highly impractical for routine checking of airline baggage where weapon incidence is small. Such devices are, however, being considered for checking small baggage samples in situations such as those posed by a hijacking or a bomb threat to a specific aircraft. An electromagnetic field device would probably be the cheapest solution if adequate performance could be achieved. Unfortunately, performance, particularly in the area of false alarms, can only be checked by an operational evaluation.

With this in mind, a contract was let with Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, to develop such an evaluation system. It will consist of three axis coils that provide oscillating fields at frequencies of 1,000 Hz, 100 Hz, and 50 Hz. The loss and magnetization caused by the passage of baggage on a conveyor belt will be measured at each frequency and stored in a computer punch tape. Testing is scheduled to begin at Dulles Airport on 19 July 1972. During these tests, an X-ray picture of each bag will be taken and correlated with the electromagnetic signature obtained. Also, during these tests, an array of various sizes of handguns will be individually inserted in random bags to determine weapon detection capability. The data obtained from at least 1,000 pieces of baggage will then be used to determine which data and what computer logic will furnish optimum performance in terms of detection and false alarms. Should the results prove to be favorable, an operational prototype of the optimum configuration will probably be constructed for further evaluation. In this event, it is anticipated a personnel and baggage system will be configured side by side utilizing common electronics where appropriate. The basic data obtained will be available for industry use in defining the characteristics required of a useable device for this purpose.

Recognizing the possibility that the electromagnetic field device may not provide satisfactory performance for weapon detection in hand-carried baggage, we are currently evaluating proposals to an RFP requesting application of new technologies to this problem. Technical evaluations are completed, but cannot be discussed at this time until a contract award has been made. It can be said, however, that at least two non-imaging concepts have been submitted that promise very high detection capability at an extremely low false alarm rate. This performance is expected on a real-time basis under the airline boarding environment which is of interest to us. One of the concepts can also be used for the detection of explosive devices. Unfortunately, the equipment cost is expected to be greater than that of an electromagnetic field device. The information from both of the above programs will be made available to anyone having an interest in baggage or parcel inspection. Also, the tests of weapon detectors and X-ray devices mentioned previously are available in published FAA reports.

CAPITOL PACKAGE INSPECTION

By: Captain James T. Trollinger, Commander, Planning, Inspection & Training Division, United States Capitol Police

The problems confronting the United States Capitol Police in providing adequate security and protection for public figures in the open environment of the complex of buildings and grounds of the Legislative Branch of the Government are many. As long as the Capitol has been in Washington, the Members of the Congress have adopted the position that their constituents should view them at work and visit with them at their office buildings. While it is true that passes to the visitor's galleries were not always as easily obtainable as they are now, nonetheless the "free and open society" concept has always prevailed. Originally, the problems of the police were limited mainly to providing protection against vandalism and the desecration of property. At one time there were only three policemen who, it should be noted, also served as guides. There was little need for the type of security which appears very necessary today. However, in present day society, there are many more public figures, many more tourists and visitors to the Legislative Branch, and many more devious means of circumventing security techniques. In addition, "anti-system" concepts and actions are being advocated by a small but aggressive minority.

When the Congress is in daily session, any constituent or any visitor from outside the United States may obtain a pass to a visitor's gallery. A separate pass is required for the Senate and the House, but the constituent can receive a pass for each House of Congress by merely visiting either his Senator's or Representative's office and signing a visitor's register. No identification or proof of any kind is required. With that pass the bearer is admitted to the visitor's gallery by a doorman whose job it is to admit any person with a pass. If that person has a camera or briefcase, he is required to check it at a place provided for that purpose. At no point along this line of events do the police have any function related to passes unless a person attempts to gain admittance without one.

When a citizen enters one of the office buildings with any type of bag, case, box, or other container, he is required to submit that container for inspection by a police officer. If the container is wrapped for mailing, no inspection is permitted, but a record is made of the addressee and the sender. If a female brings in an overnight bag and objects to an inspection, difficulties sometimes develop. No inspection is permitted of women's purses at the galleries or anywhere else, even though some of them are large enough to conceal a variety of items.

The answer to the various problems related to packages appears to be an X-ray system which is safe for the operators and for those persons whose packages are being examined. However, this presents additional problems. There are 90 different doors through which a person can enter the complex of legislative buildings. For this reason, the cost of 90 devices might be hard to sell to the Congress. Also, from 6:00 a.m. until shortly after 9:00 a.m. most of these doors are used by employees who, in most cases, do not like to be late, but who also do not allow the time to prevent it (there are 538 public figures to be protected daily, but they want their employees at work on time, unimpeded by encumbrances placed in their paths by the police). Furthermore, because of the large numbers of tourists appearing daily, it would be difficult to limit their entry at certain doors where other citizens carrying containers would pass for examination. In the Capitol Building proper, the line for the gallery often extends a distance equivalent to two blocks, particularly during the spring and summer seasons of the year. To tell these people that they must line up for package inspection before proceeding to the point where they can begin to stand in line for an hour awaiting admission to one of the galleries would be an unpopular step, to say the least. Also, during periods of inclement weather, it would not be very practical. In addition, in the opinion of some people, the installation of these systems at any public entrance would violate the "free and open society" concept. However, the places where such systems could be employed inoffensively would be at the various mail and loading platforms where all packages being sent into the complex could be examined out of sight of the legislator and his constituent. This latter approach has been formulated and is in the process of being evaluated.

Another problem which is related to X-ray systems is that of suspicious packages which have been left behind. It is the policy of the United States Capitol Police that no suspicious package be moved, covered, or otherwise disturbed. It is a fact that telephone calls are still being made by unknown persons, who state that a bomb or similar device is set to explode. Packages have been found and bomb disposal personnel have responded to disassemble them. Thus far, no explosive or incendiary devices have been found. If a package were found inside a building, a portable X-ray unit could be used to expose a Polaroid film of the contents. Bomb disposal personnel can then determine from most film whether or not the package is likely to be dangerous. We do not possess an X-ray device, but we are studying some of the various models available. It appears that what we need is a completely self-contained unit which will not be dangerous to the operators or to persons behind or around the package, but still capable of penetrating a wall or file cabinet.

When the President of the United States addresses a Joint Session of the Congress, the immediate line of succession, the Supreme

Court, the Diplomatic Corps, the Joint Chiefs of Staff, the President's Cabinet, and the Congress are all gathered for approximately one hour under one roof -- in the same room. Protection in this instance is an awesome task and no matter how frequently the event occurs, it must never be allowed to become routine, but must be thoroughly planned and coordinated. On these occasions, the requests of the Secret Service are heeded within the limits possible. Coordination and a closer liaison than that which exists daily are e established with the Secret Service, the Metropolitan Police Department, and the District of Columbia Fire Department. Every attempt is made to leave no stone unturned in establishing a security net around the House Wing of the Capitol Building -- a net which at the pre ent is devoid of any scientific, electronic devices or techniques save those of a portable nature employed by the Secret Service.

A Joint Meeting of the Congress is held to hear visiting heads of state, returning astronauts, etc. On these occasions the same public figures are in attendance, except the President. Essentially, the same security problems are present. At Joint Sessions and Joint Meetings, many special passes are issued by a variety of offices, not including the police, which permit the holders to enter the galleries. These galleries are packed with standees and those who hold seat passes. Plainclothes officers are stationed in these galleries and on the floor of the chamber. However, the press of pass holders is sometimes so great that it could be difficult to reach an individual who attempts an illegal act in time to prevent that act. Some type of device or system is needed which can effectively, efficiently, and instantly screen each person who enters a gallery.

As has been stated, such a device or system is needed when the President or other heads of state are visitors, but the need is not limited to those times only; it is needed daily when either House of Congress is in session. On these occasions, a doorman checks for a gallery pass. Plainclothesmen are in the galleries. However, it is quite possible that a person with a gun, grenade, etc., could have time to make some use of his weapon before his apprehension could be effected. If a system or device can be designed which is highly effective and efficient; small and unobtrusive in configuration; and economical in cost, operation and maintenance; then a ready market should exist for all legislative bodies -- city, county, state, and federal -- and for courts, banking institutions, and others.

As an alternative to such a system or device, a very lightweight, clear, undistorted, scratchproof, hard, glass type material which is capable of stopping a calibre .357 magnum bullet will receive considerable study by the Architect of the Capitol. That office has been evaluating bulletproof glass; but glass which is lightweight cannot stop a .357 magnum bullet from making a hole through which a revolver barrel can be pushed and fired. Weight is the main problem at the House and Senate Galleries. The bulletproof material must be light enough to be mounted atop the present gallery rail without requiring to any considerable extent support from either the floor below or the ceiling above.

Everyone is aware of the bomb explosion which occurred in an obscure men's room in the Senate Wing of the Capitol on March 1, 1971. On that date a Planning Division was created within the Administrative Staff of the United States Capitol Police. A recommendation is now pending in the United States Senate which will authorize funds for the procurement, installation, and maintenance for one year of a three-unit security system featuring:

1. A closed circuit television to watch the out-of-the-way areas.

2. An intrusion detection system to alert police personnel when entry is attempted via windows and certain other places.

3. The package inspection system just discussed.

The proposed closed circuit television system is designed to survey areas or doors through which a person can pass, either entering or leaving one of the buildings or areas within the buildings, without passing a police officer. In the system's daytime configuration, certain out-of-the-way public areas will be viewed on dedicated monitors with the intent of preventing a repeat of the March 1 incident. Those areas are the ones which an officer cannot patrol for various reasons, or is not assigned to on a 24-hour basis. The system will use a motion detection system which will eliminate the need for a monitor for each camera. The cameras are zoned, with no more than 12 cameras per zone. During the periods when the camera sites are supposed to be in a secured status, each zone will operate under the motion detection system, with video tape recorders recording the intrusions as they occur. A hard copy printout will record the date, time, and location of the intrusion, as well as give an indication of the recorder and where the tape is to be found.

Except for the unreasonable, unlawful, and unconscionable physical search of each person entering the various buildings, there is no safe 100 percent reliable system known which will enable the Chief of the Capitol Police to state, "There is absolutely no way a dangerous weapon or device can be smuggled into the Capitol Buildings." Such a state-of-the-art is the acme of perfection for security systems, and until it is developed, a combination of vigilance, training, planning, and technology will be required to accomplish the task.

DEVELOPMENT OF EQUIPMENT FOR THE PROTECTION OF TRAVELING PUBLIC

By: Dr. Michael Lauriente, Office of Systems Engineering, Department of Transportation

Gentlemen: I will add some statistics to what Tom Bell has given you. Almost half a million passengers are flying everyday in the United States alone, and of the order of about 80 billion passenger-miles per year. One airline security specialist estimates the hijacker as being one in 6 to 8 million passengers. This gives you some estimate of the magnitude of the problem that the industry is facing. I also should add, and I am sure you all know this, that most of this loading occurs for a couple of hours in the morning, and a couple of hours at night. When the holidays arrive, the system gets its severest test.

The Figures incorporated in this presentation represent the results of a crash program undertaken by the Department of Transportation to meet this problem. In December of 1970, the President made his proclamation to protect U.S. citizens and air commerce from the menace of air piracy. Following this announcement, a facility at the Transportation Systems Center of the Department of Transportation (DOT) was established for test and evaluation of devices that could be applied to the insidious problem of hijacking and sabotage. This effort was reported in the format of a consumer's digest[1] and in a technical report[2] on the state-of-the-art of devices. In order to compare the metal detectors, it was necessary to devise a set of reproducible laboratory test conditions. A typical test setup is shown in Figure 1. If you look carefully, you will see a revolver mounted on a plastic frame. It was determined early in the study that the rate of velocity of the weapon past the sensing device could affect its detection. This characteristic occurred for models with an automatic balancing bridge circuit. Data were taken for weapons at different velocities and locations. Data were also taken with individuals carrying the weapon to simulate typical real life situations. The weapon detector shown is the Rank Unit. Figure 2 shows a schematic of the two basic types of weapon detectors, as given in Popular Mechanics.[3]

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[1] A. E. Barrington, L. Frenkel, A. Landman, "Technical Evaluation of Metal Detectors for Concealed Weapons," DOT-TSC, 71-15, June 1971.

[2] A. E. Barrington, L. Frenkel, J. E. Cline, A. Landman, "FY 71 Engineering Report on Surveillance Techniques for Civil Aviation Security," DOT-TSC-OST, 71-20, November 1971.

[3] Wahl, P. "How Science Will Foil The Skyjackers," Popular Mechanics, November 1970.

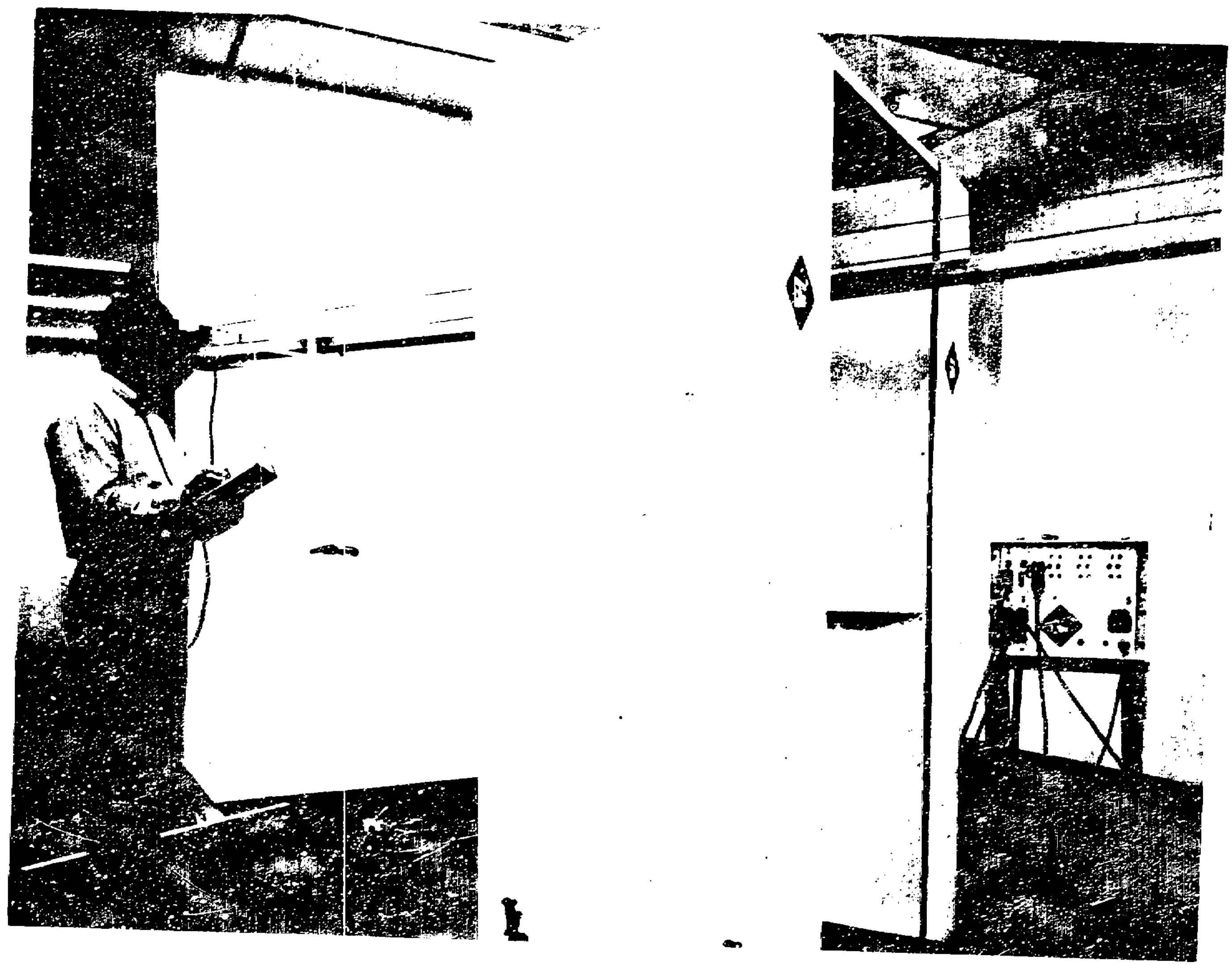

Figure 1. Typical Test Setup For Metal Detectors

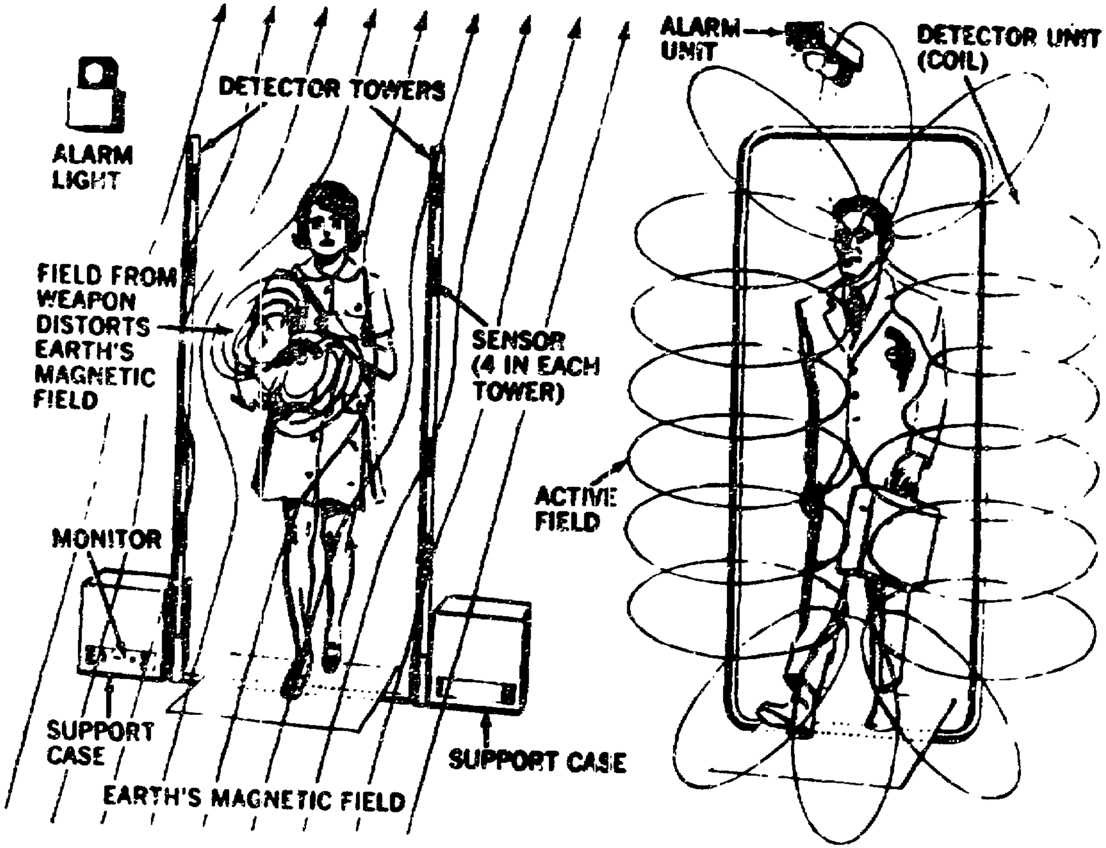

Figure 2. Disturbances in Earth's Magnetic Field Are Sensed by the Magnetometer (above left) Where Weapon Passes Between Its Detector Towers. Active Field Metal Detector (above right) Creates Its Own Magnetic Field And Signals When Weapon Carried Through Disturbs It.

Figure 3 is a Transfrisker Hand Search Unit. This device contains a capacitance-inductance bridge which is detuned by the presence of all metals. The amplitude of the audio frequency increases in proportion to the quantity of metal detected. Discrimination between innocuous objects and weapons is possible with a little training. It is an all-metal detector selling for around $600. It operates at 10 kilohertz, and is the weapon detector that has been recommended by the U.S. Army Land Warfare Laboratory, Aberdeen, Maryland.

Figure 4 is the Rens Squealer. It sells for around $350 and operates at 500 kilohertz. The device operates with two oscillators at 450 kilohertz. One of these is coupled to a search loop and the difference frequency is fed to a speaker. It is also sensitive to all metals. These hand-held devices are excellent when there is a high threat. They are an improvement over hand-searching, but where large numbers of passengers are handled, walk-throughs would obviously be more feasible.

Figure 5 is the Riwosa, which is manufactured in Switzerland. It sells for $170 and operates at 150 kilohertz. Its characteristics are similar to the Rens Squealer. It is presently used by all BOAC crews prior to boarding of passengers. Figure 6 is the Excelsior and sells for $150. It operates at 700 kilohertz. This device uses two oscillators. One of these is coupled to the loop. The difference frequency is fed to a speaker.

Figure 7 is a Rank walk-through. It sells in the price range of $5,000 to $6,000 and operates at 10 kilohertz. Three field coils are located in each side of the doorway to yield a uniform field. This model was found to have high sensitivity but little discrimination capability. Figure 8 is the Westinghouse, which has been discussed previously. It sells for about $8,000. It operates in the 93Hz and 750Hz frequency regions. The field coils provide three spatial axes and a logic circuit achieves the required discrimination. Originally sponsored by the Federal Aviation Administration, it has since been adopted for further study by the Army.

Figure 9 is a very interesting system manufactured by OutoKumpu Oy of Finland and is called the Meteor. Its origin stems from a need in the foundry to separate metal from sand. The company adapted the industrial design for airline security at Helsinki airport in Finland. It has been under test at O'Hare International Airport in Chicago in the International boarding area. It sells for around $5,000 and operates at 380 hertz. The primary field coils are located on one side of the doorway and the secondary field coil on the other. Several field reversals occur throughout the doorway which very effectively provide pickup of the weapon regardless of its orientation.

Figure 10 is typical of the first generation metal detectors that were put into operation at the airports. It detects changes in the earth's magnetic field and sells for around $1,300. It has the fluxgate type of detector and is a passive system. Figure 11 is the Schonstedt which is very similar in appearance and operation. It sells for $1,000. It is manufactured in Reston, Virginia. Figure 12 is the Densok system in operation at the Tokyo airport. It markets for $1,200. Among the active magnetometers, this is probably one of the cheapest. On the other hand, according to the rating sheet, it does lack some of the discrimination features of some of the more expensive active systems. This device has a single field coil in a bridge circuit operating at 3,400Hz. Impedance changes in the coil unbalance the bridge circuit which in turn stimulates an oscillator at a signal amplitude equivalent to the signal.

Figure 13 is the early model of the Sperry Rand. It is an active magnetometer selling for about $2,000. Figure 14 is the Excelsior walk-through. It sells for $1,800. The coil system consists of three field coils located at the entrance, center, and exit, respectively. The center is used as a primary at 25KHz. The outer coils are used as secondaries and are connected in opposition. The signal output when the coupling is unbalanced is amplified.

Figure 15 is a flow-sheet of our anti-sabotage concepts. The first column--Tagging--is a subject that should get more attention. Unfortunately, all ideas proposed have been rejected. As for the second column--Affluent Detectors--you'll hear more about the dogs and some of the other instruments on the program. Some are considered "blue-sky" at this point. X-ray imaging is known to this audience; therefore, there is no need to dwell on the subject. The last category is "Neutron Activation." FAA sponsored a field demonstration in Los Angeles where a few discrimination problems turned up. It is now back in the laboratory for further feasibility study.

As a result of the combined efforts of FAA, the Postal Service, and others, in their determination to come up with film-safe X-ray techniques, I have portrayed in Figure 16 a radiation chart just to show you the advances that have been made. You will note the scale on the left-hand side at around 10 to 100 roentgens. This is the radiation that you normally receive for a chest X-ray. You will note that it is on the border of being somewhat hazardous. Our technology has brought radiation limits way down. Hopefully, these will be used some day in hospitals.

Figure 17 portrays a tribute to some of the pioneer efforts on the part of FAA sponsored studies at Illinois Institute of Technology Research.[4] It was one of the first bomb-sniffers conceived. It may

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[4]Zinn, Samuel V., Jr., "Evaluation of a Chemosensor for Detecting Dynamite Aboard Aircraft," Report No. FAA-DS, 70-5, March 1970.

appear rather awkward, but remember it was the first of its kind. Figure 18 is a modern system embodying the same principles. Through use of solid state circuits and packaging, a portable operational system was achieved.

Figures 19, 20, and 21 show, respectively, a schematic of the Norelco Pulse X-ray System, a schematic of AS&E Flying Spot Scanner, and the Norelco Model 5400 A, which uses a continuous radiation X-ray source. I understand the Air Force has several of the Norelco models in use. Figure 22 shows one of the concepts that DOT is studying for counter checkin. That sketch is also from Popular Mechanics.

This concludes this very brief sketch of the technology in development for protection of the traveling public.

Figure 3. Transfrisker #6010

Figure 4. Rens Squealer Model 15

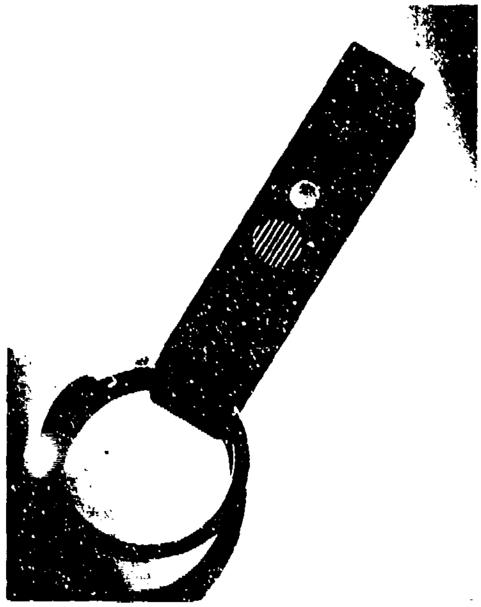


Figure 5. Riwosa Metal Detector MD-12

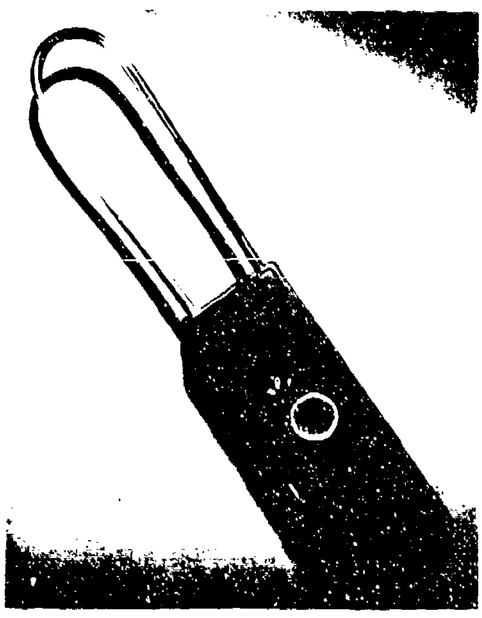


Figure 6. Excelsior Hand-Held Detector

Figure 7. Rank Metal Weapon Detector MWD/AIR I

Figure 8. Westinghouse WD-4 Weapon Detector

Figure 9. Meteor Airport Security Metal Detector

Figure 10. "Friskem" Walk-Through *Station Type I*

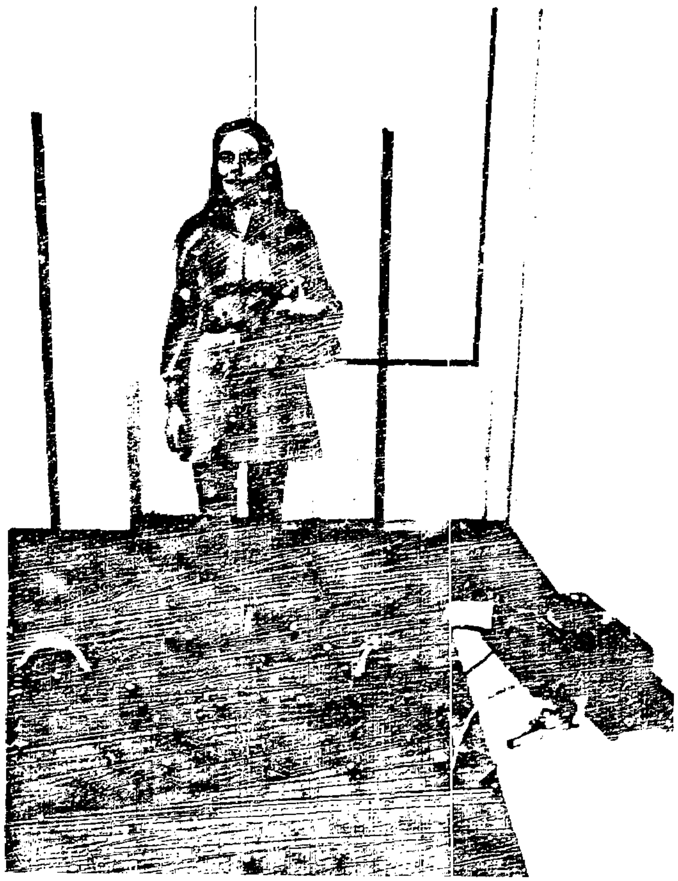


Figure 11. Schonstedt Magnetic Surveillance SD2

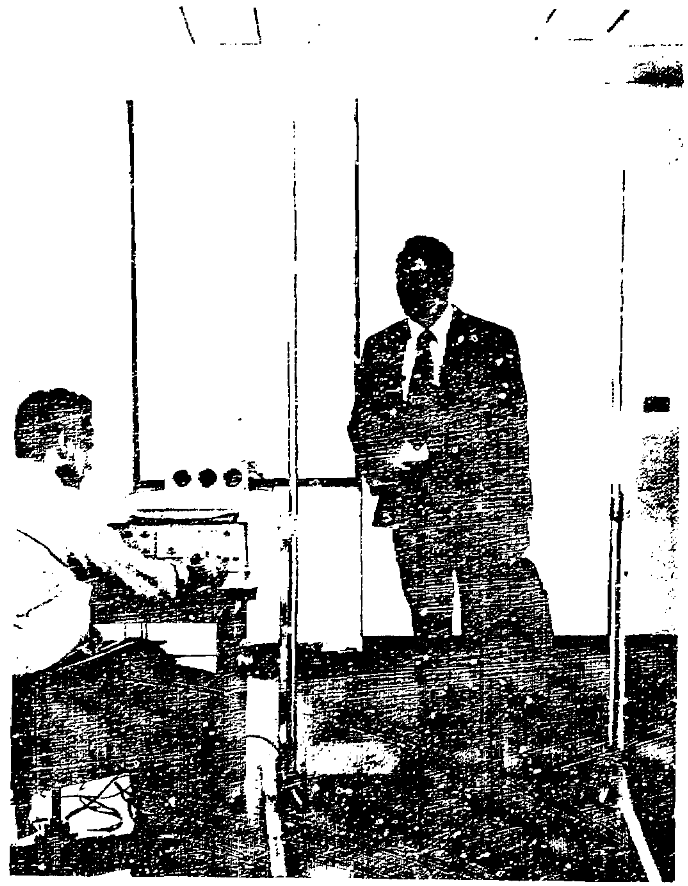


Figure 12. Densok "Magnetic Eye" Type MGG

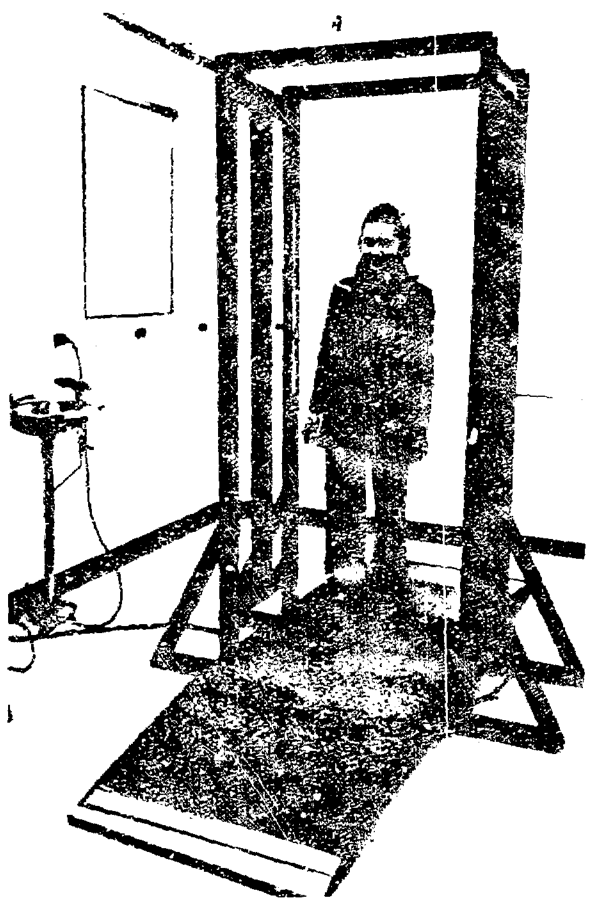


Figure 13. Sperry Weapons Detector SMD-1000

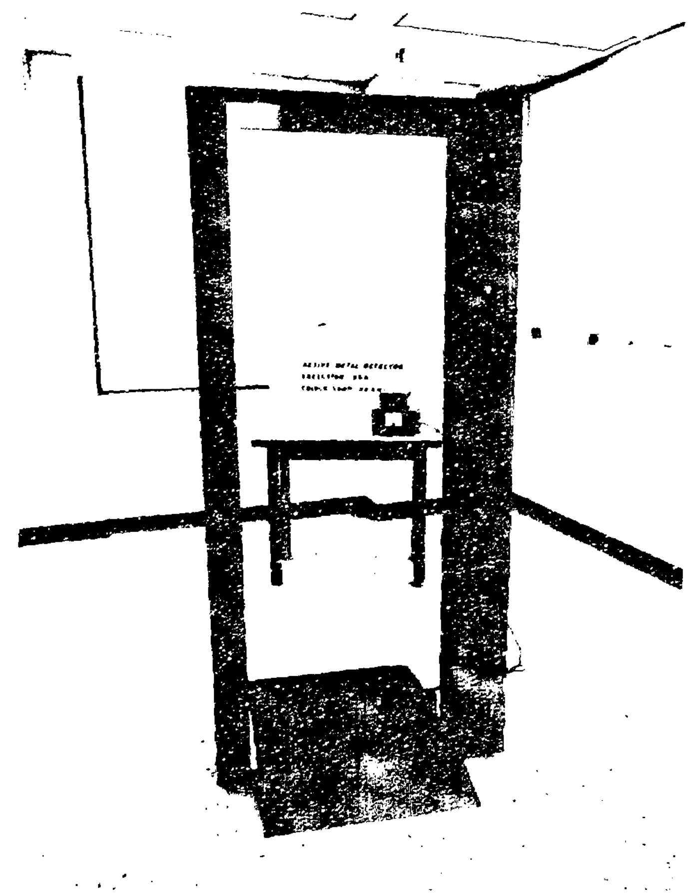


Figure 14. Excelsior SG-2C Metal Detector

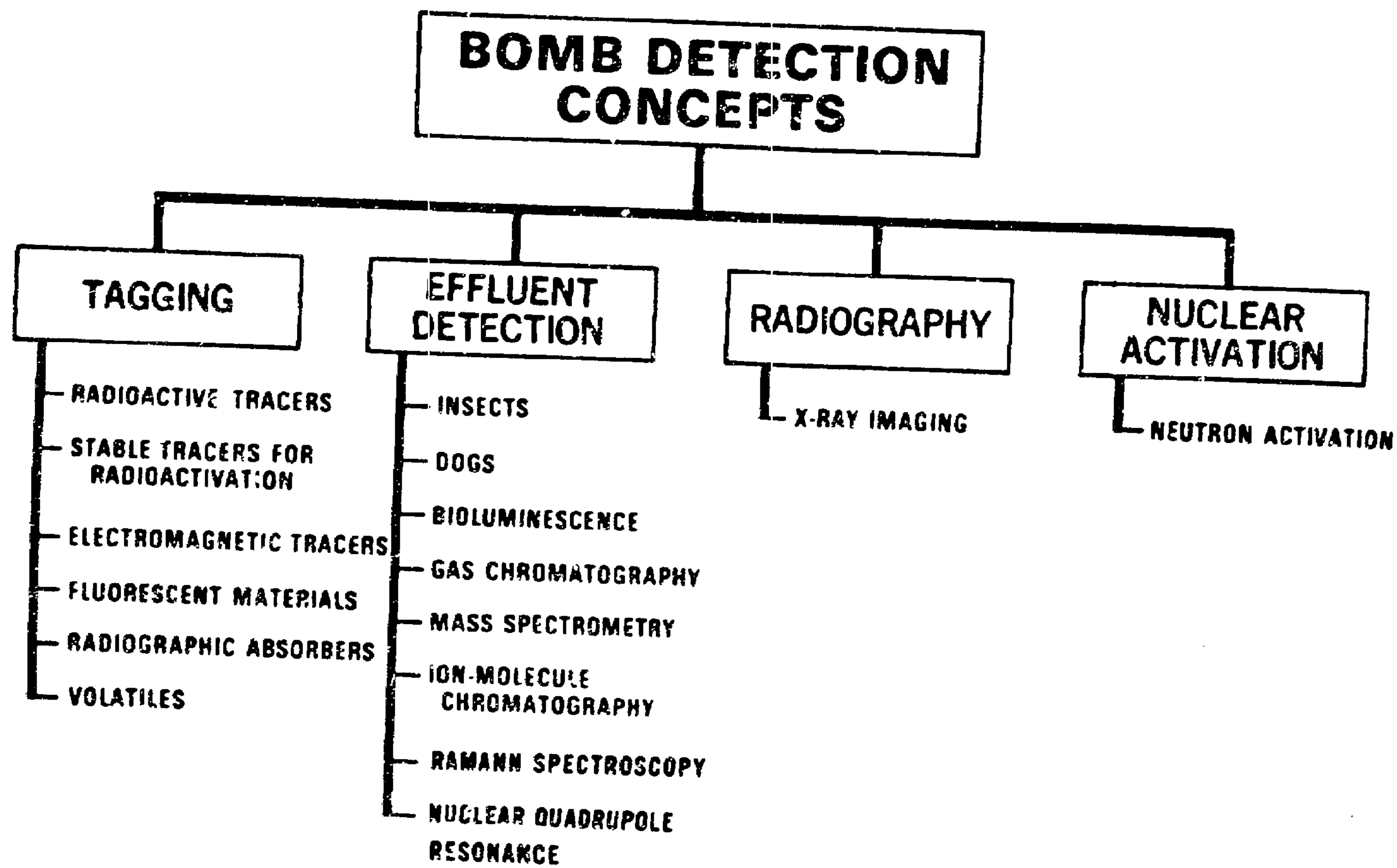


Figure 15. Bomb Detection Concepts

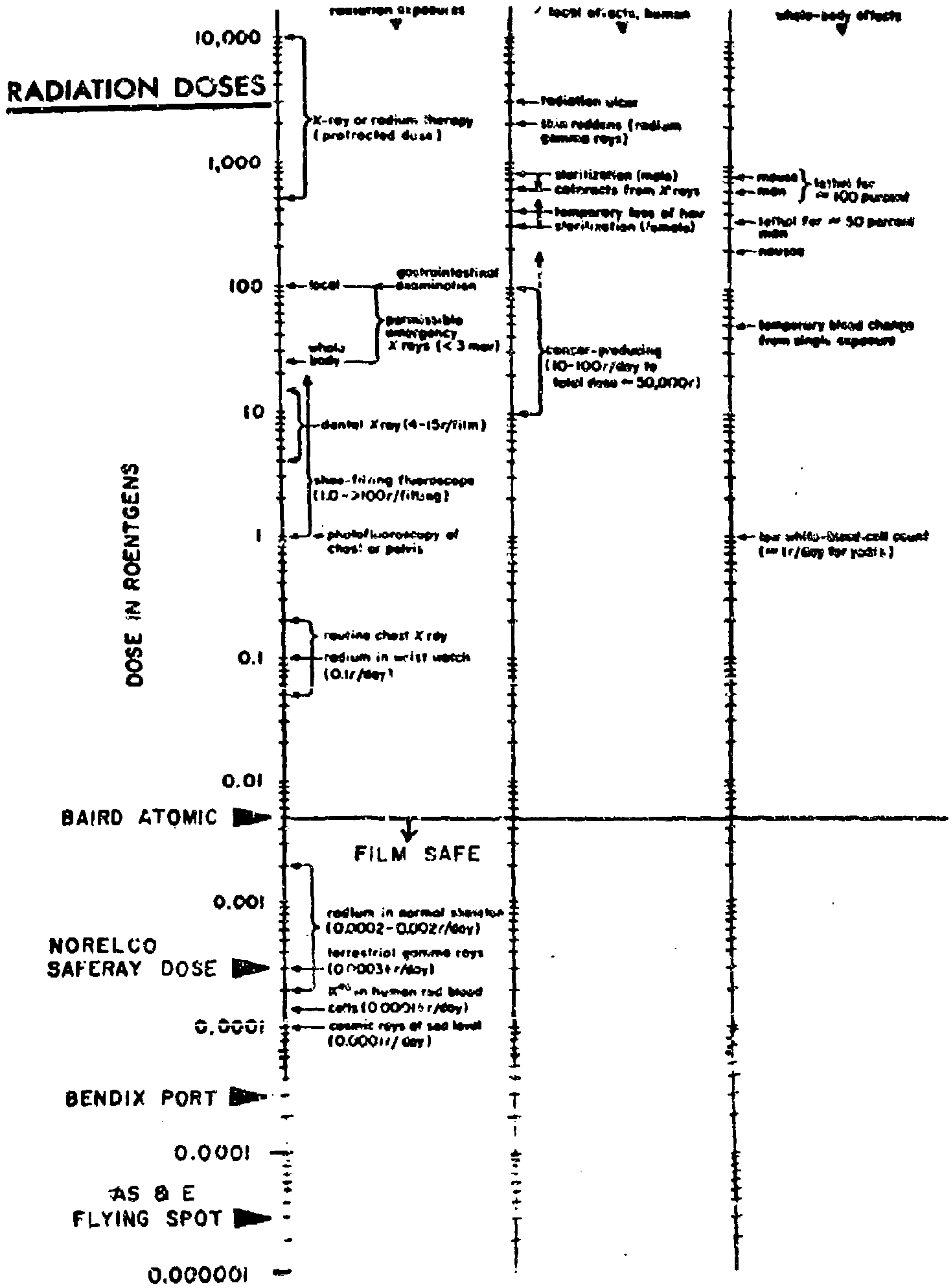


Figure 16. Radiation Dosage Chart

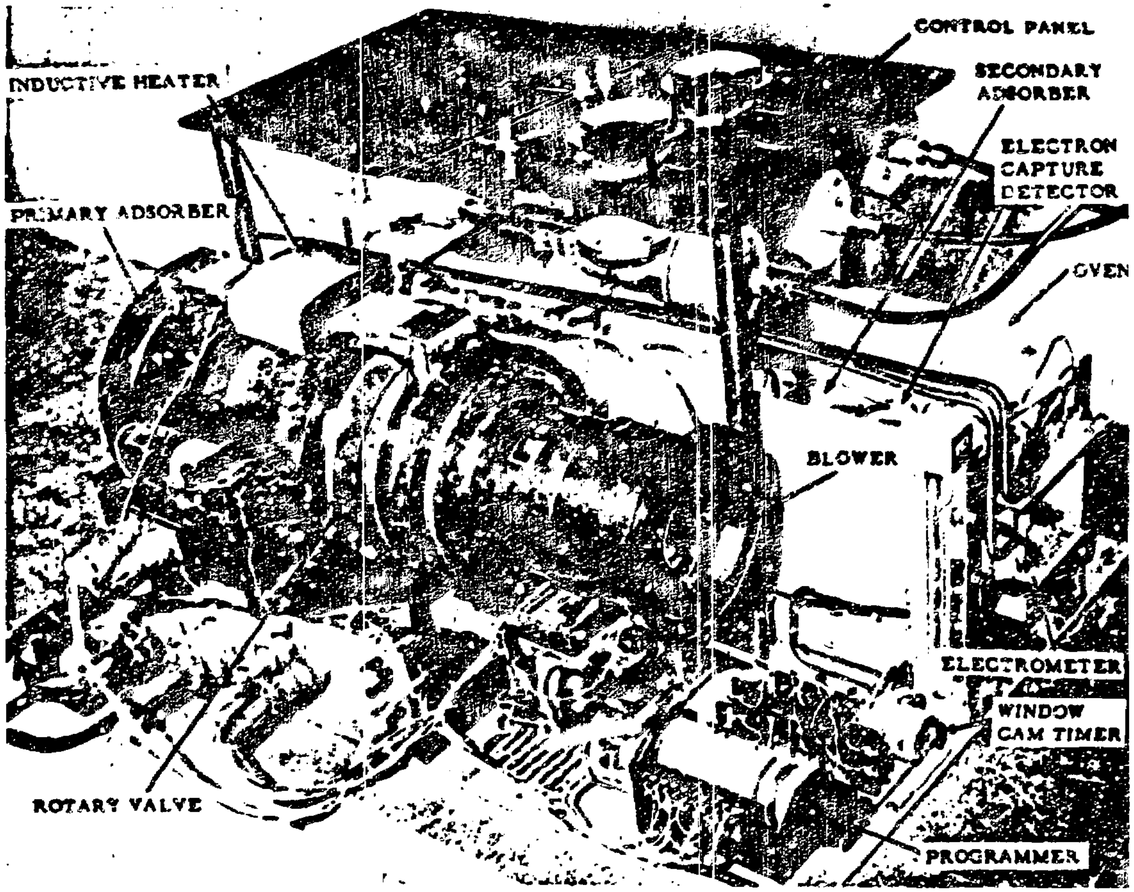


Figure 17. Early Model Explosive Sniffer

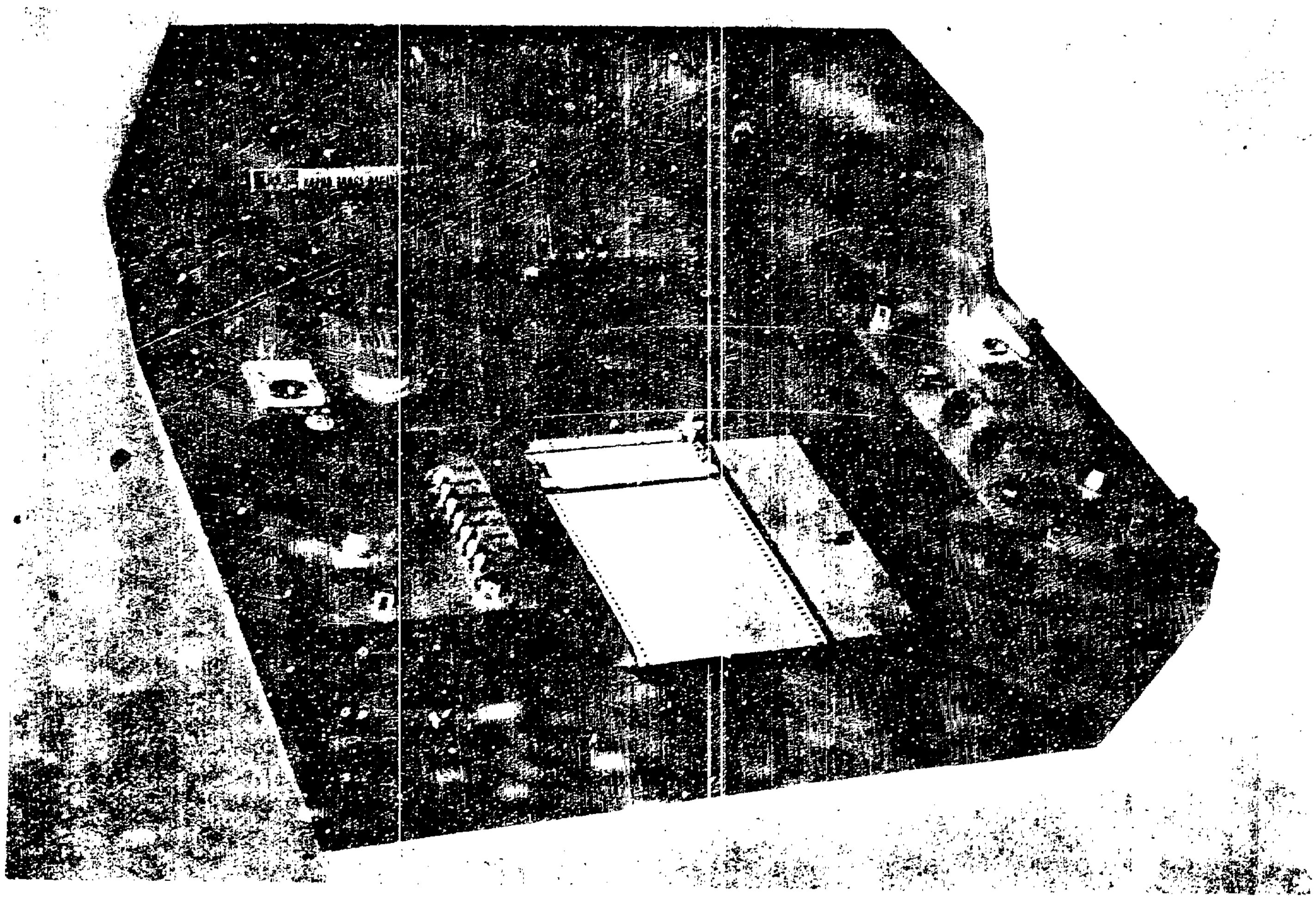


Figure 18. Hydronautics Vapor Trace Analyzer Model 103A

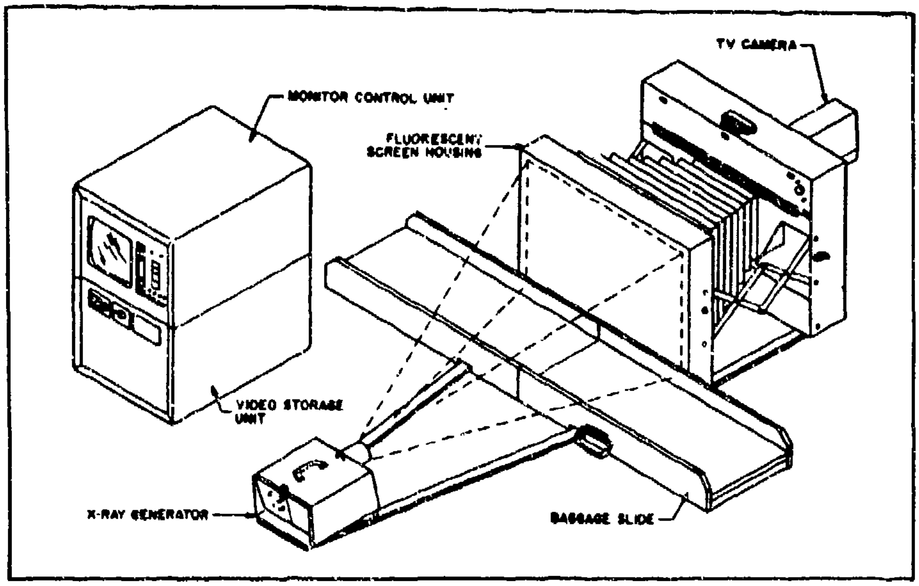
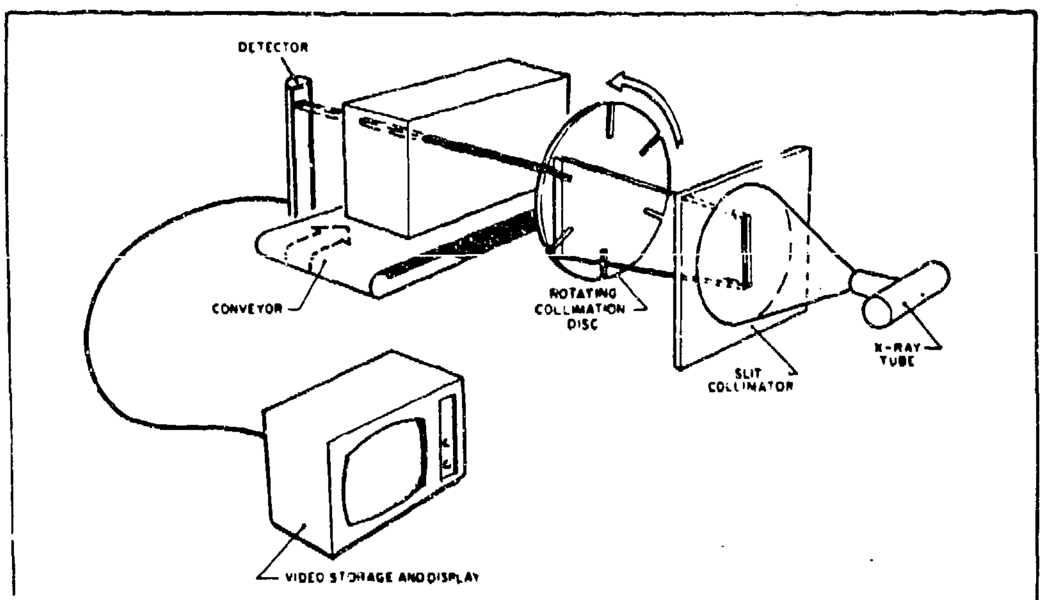


Figure 19. Norelco Pulse X-Ray System



Principle of Operation of FSIS System for Parcel Inspection

Figure 20. A.S. & E. Flying Spot Scanner

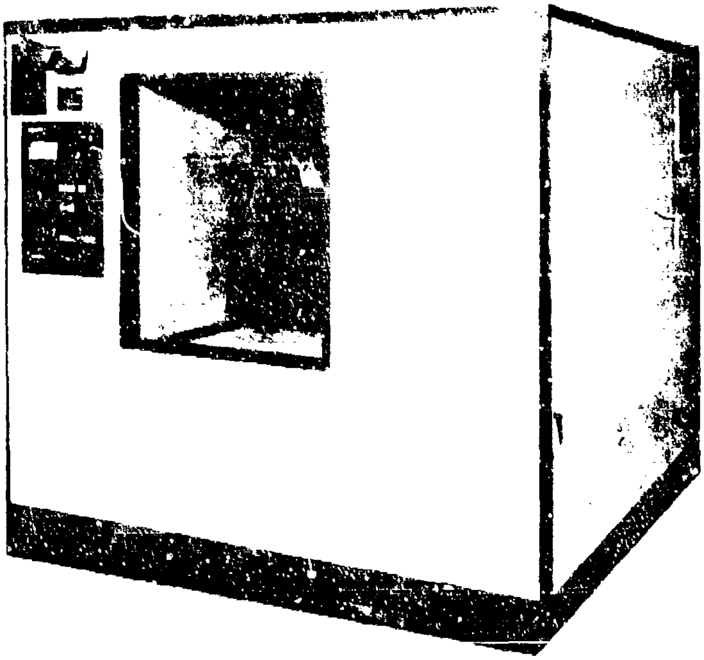


Figure 21. Phillips Electronics Instruments
DynaFloor Fluoroscopic Inspection Unit

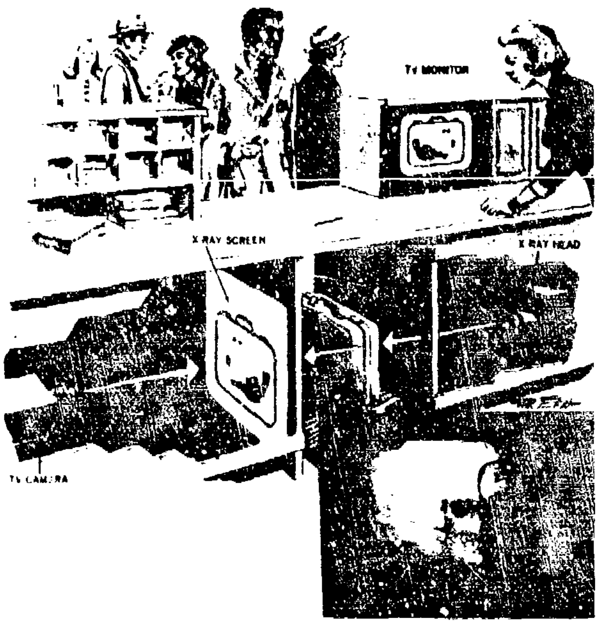


Figure 22. X-Ray Systems Concept for Check-In Counter

OVERVIEW OF THE CIVIL AVIATION SECURITY PROGRAM

By: Thomas Bell, Inspector, Civil Aviation Security, Office of Transportation Security, U.S. Department of Transportation

You may wonder why the Department of Transportation (DOT) has an interest in the protection of public figures, and how the Department fits into the scheme of things. Many of you who are already involved have traveled with public figures. Whether you've come in contact with the Civil Aviation Security Program or not, you will be affected by it at some time or another in the future. If you travel as a law enforcement officer, you are already aware of the notification requirements for carrying firearms aboard aircraft.

An aspect of the program is that of the public figure. When we think of a public figure, we think of the VIP. But I can't think of more important VIPs than those of you who are sitting right here. You have probably traveled on commercial aircraft on many occasions. The Civil Aviation Security Program of the DOT, as directed by President Nixon, is designed to protect you as a member of the traveling public. Now, whether you are a public figure or a VIP in your own estimation--we think you are both--you are a public figure when you walk the streets of the United States. I think (regretfully, as we learned in the last 24 hours) it is becoming more hazardous each day to walk safely on the streets of the United States. I am reminded of an expression attributed to a militant youth leader, "Violence is as American as apple pie." Symbols of Americanism and of patriotism since the forties and fifties have been the American Flag, J. Edgar Hoover, apple pie, and motherhood. We have seen the American Flag desecrated, J. Edgar Hoover scurrilously attacked, and motherhood scoffed at. Now, the only symbol unassailed is the apple pie--and it probably contains a little DDT. None of these symbols are above attack. Now, our national air transportation system is also under attack.

Crime in aviation (Figure 1) is really what I am going to talk about. No one knows how far back it goes, whether it goes to the days of the Wright Brothers or not. The Civil Aviation Security Program of today--even though we may think of it as a relatively new program--is not really that new; but the threat to our national air transportation system is more meaningful today than say, several years ago. In recent months, hijackings have escalated from past incidents involving political refugees or homesick Cubans wanting to flee the United States to fleeing felons, escaped prisoners, and wild-eyed extortionists with bizarre plots. Hijacking is a very dangerous situation, and we are concerned about the attitude of the public. For example, one extortionist, D. B. Cooper, was portrayed by the news media as a "Robin Hood of the air." Looking at the real threat, the lives of approximately 150,000 innocent passengers have been exposed unnecessarily to these dangers. Approximately 1,500 crew members have been threatened by hijackers. Those of you who are pilots know that it's bad enough when the weather

	DEATHS	INJURIES	AIRCRAFT	INCIDENTS
HIJACKINGS				128
PASSENGERS - KILLED	2			
WOUNDED/INJURED		5		
CREW - KILLED	3			
WOUNDED/INJURED		9		
HIJACKERS - KILLED	2			
WOUNDED/INJURED		5		
SUICIDE	1			
AIRCRAFT DAMAGED			4	
SABOTAGE				7
AIRCRAFT LOST/DAMAGED			7	
LIVES LOST	124			
OTHER - UNDETERMINED				1
AIRCRAFT LOST			1	
PASSENGERS KILLED	44			
PASSENGER SUICIDE	1			

	1970	1971
BOMB THREATS	600	1,000 +
PASSENGER INJURIES	25 - 30	40 - 45
PASSENGER DELAYS - ESTIMATED HOURS		250,000
AIRCRAFT DELAYED/DIVERTED		400

177 LIVES LOST — 11 AIRCRAFT LOST/DAMAGED — ALMOST 100 PEOPLE INJURED

Figure 1. Crimes Against Air Transportation System (U.S. Aircraft 1961-1971)

changes, but this, combined with flying to a strange alternate airport is even worse. I am sure you know how you would feel if a man were behind you with a gun, directing your course of action and telling you to fly the plane in a manner contrary to common sense and judgment. Every time a pilot loses command and control of his aircraft, the hazards and the risks go up tremendously. Fortunately, and we've had our fingers crossed, there have been no major catastrophes as a result of these crimes. The recent hijacking incident from Allentown, Pennsylvania, to Dulles Airport resulted in a New York article describing the real fear felt aboard this aircraft. This means a lot to all of us, not only for ourselves (or VIPs), but for our families, relatives, and friends. Many of us wonder, when we put loved ones on an airplane, whether they are going to be subjected to uncontrolled risks during the flight.

Some people think hijacking goes back to 1930 (Figure 2). Recent investigations by Dr. John Daily, FAA aviation psychologist, discloses that air crimes go back as early as the 1920s. French aviators, forced to land in North Africa, were kidnapped by Arab tribesmen and held for ransom. There was an incident in the early 1930s when those on a Pan American survey flight escaped capture by Chinese pirates. We continue to learn, historically, about the threat to the air transportation system. Only recently, a Life magazine article appeared which recounted the Hindenburg explosion some 35 years ago. It indicated that the Germans were very much concerned about sabotage, searching it thoroughly before its last flight. It reportedly had armed guards aboard--probably the first recorded example of sky marshalls.

Another comment is appropriate on the evaluation of the threat. In a recent FBI Law Enforcement Bulletin, Captain David Hansen of the Daley City, California, Police talked about violence in this country. His quotation: "What is safe, when even police stations are bombed?" Many policemen in this audience have found bombs in public buildings. Even our Nation's Capitol was recently bombed. The situation is indeed a very serious one.

President Nixon initiated the current Civil Aviation Security Program (Figure 3) following the Lebanon incident. Aircraft were captured by the Arabs and blown up. Action was immediate. Back in 1961, following the first United States hijacking, FAA established a Federal Air Guard Program. Flight inspectors were trained to carry firearms and covered flights considered to be high risk, or flew on special request. In 1968, when hijacking reached rather epidemic proportions, the FAA was again called upon to act. It formed the Hijacking Task Force, the first utilization of an interdisciplinary group designed to come to grips with the problem. As a result of their efforts, the passenger screening system of today was developed, along with the behavior profile. There have been no dramatic or unusual changes in the program since then, other than greater emphasis on the problem. From the theme of this conference you can see that the technical devices that we are trying to utilize are moving along.

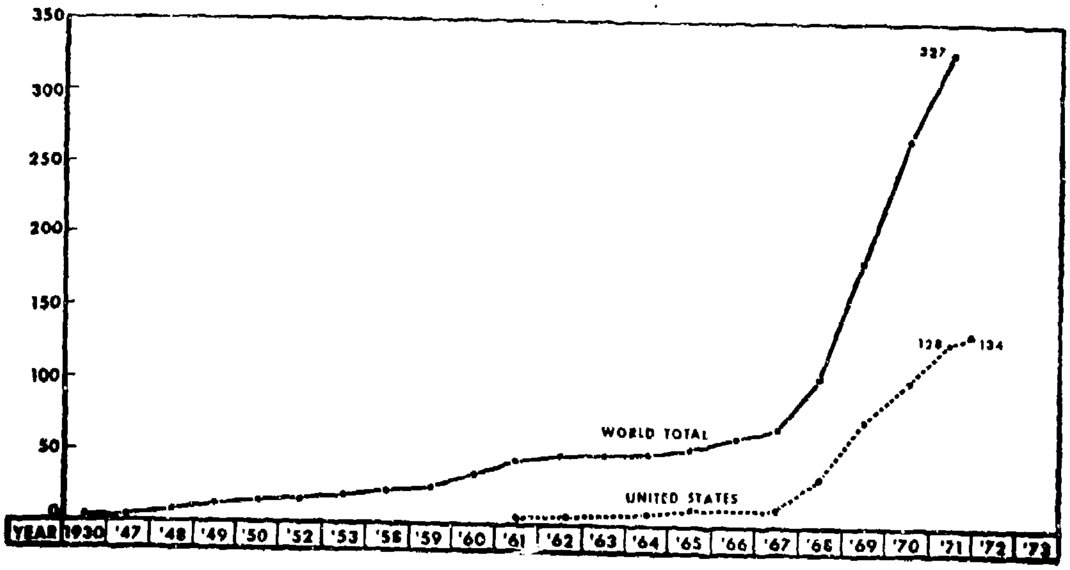


Figure 2. World Wide Hijackings--1930 to 1971 (Cumulative)

THE MENACE OF AIR PIRACY MUST BE MET - - IMMEDIATELY AND EFFECTIVELY

TO PROTECT U.S. CITIZENS AND OTHERS ON U.S. FLAG CARRIERS

- **PLACE FEDERAL ARMED GUARDS ON U.S. COMMERCIAL AIRLINERS**
- **EXTEND USE OF SURVEILLANCE EQUIPMENT AND TECHNIQUES**
- **PROVIDE GOVERNMENT ENFORCEMENT OFFICERS TO CONDUCT SEARCHES AND ARRESTS**

DEPARTMENTS WILL ACCELERATE EFFORTS TO

- **DEVELOP SECURITY MEASURES AND**
- **NEW METHODS TO DETECT WEAPONS AND EXPLOSIVES**

SECRETARY OF TRANSPORTATION WILL DIRECT PROGRAM WORKING CLOSELY WITH SECRETARIES OF STATE, TREASURY, DEFENSE AND THE ATTORNEY GENERAL

PRESIDENT NIXON
SEPTEMBER 11, 1970

Figure 3. The President's Call for Immediate Action on Air Piracy

In September 1970, President Nixon indicated that the menace of air piracy must be met, and he gave the Secretary of Transportation the responsibility to direct this program with the assistance of the Secretarys of State, Treasury, and Defense, and the Attorney General. As a result, the DOT is fielding what I like to call a team of teams. This team is quite big, as you can already see. Within the Department of Transportation, we have the FAA. The other Government Agencies involved are the Treasury Department, the FBI, and the United States Marshals Service. From industry, we have the Air Transport Association, the air carriers, the Airline Pilots Association, and the Airport Operators Council International, and others. Each of these groups has, in addition to its own security interests, responsibilities and involvement in the program. Within the DOT we try to weld this team (or team of teams) together into one unit, for a single, unified purpose, and that is to keep hijackers off aircraft. As of January 1972, there were 128 hijacking incidents, some of which were sabotage, and the figures indicate the number of passengers or crew killed or injured. These figures may not seem large, but everyone of those kinds of incidents can threaten the lives of up to 300 or more people.

Weapons involved (Figure 4) are principally firearms and bombs, alleged or real. These are the two types most used by hijackers. Through technology, we hope weapons will become easier to detect. Bombs are very difficult. I'm hoping technology will improve upon that.

Figure 5 shows the missions of the Civil Aviation Security Program. The goals and objectives of the program are aimed at eliminating hazards to the passengers. One of the most important objectives is the last item (Figure 6). Educate not only the general public, but also the flight crews. Sometimes a feeling of a "will to resist" on the part of air crews might successfully terminate some hijackings. By this I don't mean any foolish or hazardous actions.

In the DOT (Figure 7), the Office of Safety and Consumer Affairs is headed by General Davis. I am sure many of you may know him personally, and others may know of him by reputation. Under him are several offices, one of which is the Office of Transportation Security, which includes the Civil Aviation Security Division. The Federal Aviation Administration (FAA) has the responsibility for the operational implementation and executive direction of the program. One important point is that this program is an important one among the many personally followed by the President.

Manpower is charted back to September 1970 (Figure 8) and you can see the rapid rise in people. The large black line at the top is the total Customs Security Officer (CSO) force, numbering around 1200 people. Current plans are to start a downward trend on the total number of CSOs. The line that you see labeled "AIR" will start a downward trend, and the ground duty will go up considerably. In other words, ground security and ground screening processes will be emphasized. The other forces will

TYPE	1961 - 6/70	7/70 - 12/71	TOTAL
FIREARMS ALLEGED & REAL	55	32	87
KNIVES	20	1	21
BOMBS ALLEGED & REAL	14	21	35
RAZORS OR BLADES	3		3
B-B GUN	1		1
TEAR GAS PEN	1		1
BROKEN BOTTLES	1		1
ICE PICK		1	1
HATCHET		1	1
ACID		1	1
FIRE THREAT		1	1

Figure 4. Weapons Involved in U.S. Hijackings--1961 to Present

CIVIL AVIATION SECURITY

MISSIONS

ELIMINATE THREAT OF AIR PIRACY AND SABOTAGE IN U.S. CIVIL AIR COMMERCE.

PROTECT U.S. CITIZENS AND OTHERS WHILE ABOARD U.S. FLAG CARRIERS, FROM UNLAWFUL ACTS IN THE NATIONAL AND INTERNATIONAL AIR TRANSPORTATION SYSTEM THROUGH SECURITY/SAFETY MEASURES.

Figure 5. Civil Aviation Security Missions

GOALS AND OBJECTIVES

1. REDUCE OR ELIMINATE ALL HAZARDS TO PASSENGERS AND AIRCRAFT FROM UNLAWFUL ACTIVITIES.
2. PREVENT INTRODUCTION OF DANGEROUS WEAPONS OR MATERIAL INTO THE AIRCRAFT/PASSENGER ENVIRONMENT.
3. ACCELERATE DEVELOPMENT OF COMPREHENSIVE CIVIL AVIATION TRANSPORTATION SECURITY PROGRAMS AND THE EXCHANGES OF INFORMATION AND INTELLIGENCE FOR THEIR SUPPORT.
4. DETER OR PREVENT HIJACKING OF AIRCRAFT.
5. CONTROL THE PROTECTION/SECURITY PROCESS FOR AIRPORT, SERVICE FACILITIES, AIRCRAFT.
6. DETECT THREATS/HOAXES AFFECTING FLIGHT/GROUND SECURITY-SAFETY ENVIRONMENT.
7. EDUCATE THE GENERAL PUBLIC, THE AVIATION INDUSTRY AND THE FLIGHT CREWS TO THE PERILS, AND THE GOVERNMENT'S EFFORTS TO ELIMINATE OR REDUCE THREAT.

Figure 6. Civil Aviation Goals and Objectives

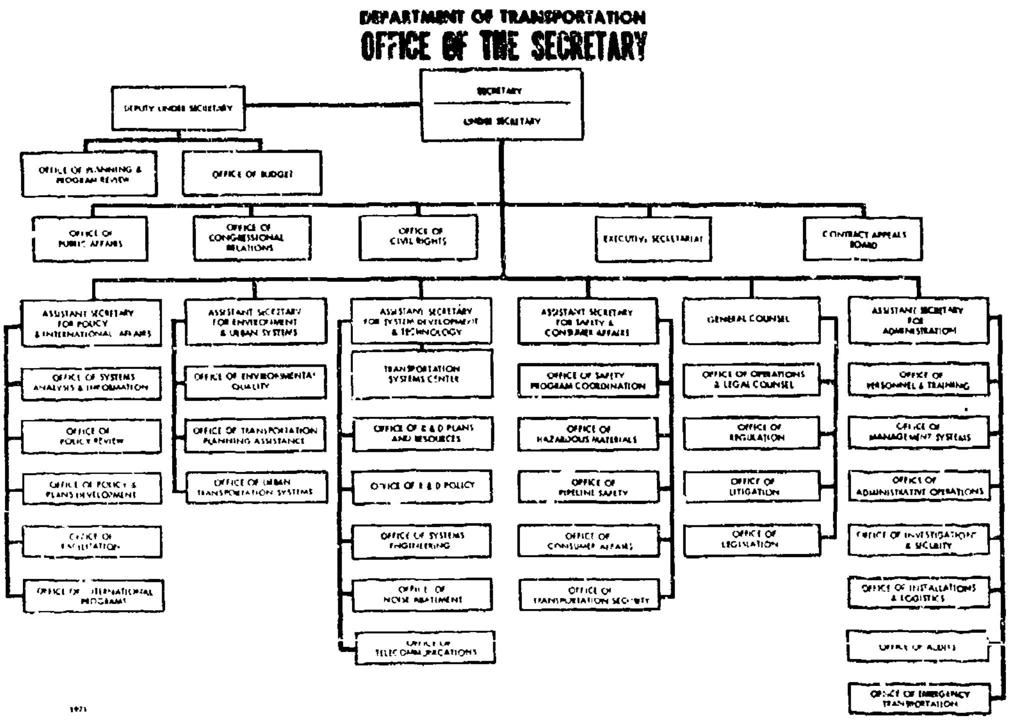


Figure 7. Organizational Chart--Department of Transportation

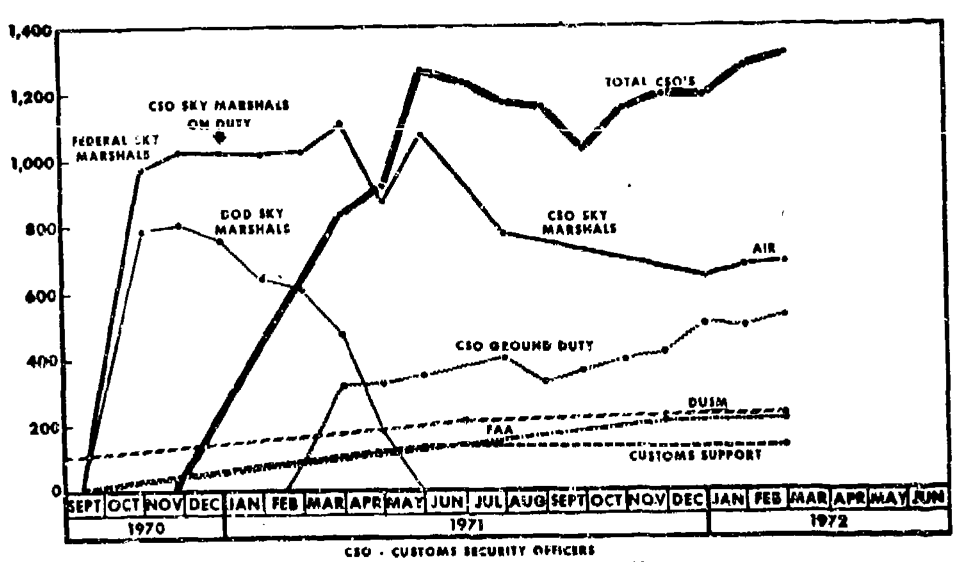


Figure 8. Civil Aviation Security Program Manpower Utilization

remain at an essentially level position. As we reduce the Federal law enforcement presence, we will rely on local law enforcement authorities in those cities involved with security responsibilities for their airports.

FAA's regional setup (Figure 9) is decentralized. There are nine regions in the United States, and each of the places with a diamond is known as a "key airport." There are 33 in the United States, with an Air Transportation Security Officer (ATSO) from FAA who works in conjunction with the Deputy United States Marshals or the Customs Security Officers to provide the Federal law enforcement presence. The ATSO is also responsible for the other local airports in his area. For example, here in the Washington, D.C., area, Jack Birkenstock at Dulles International Airport, is responsible for the program and for developing local law enforcement support at Richmond, Norfolk, Roanoke, and other smaller cities in Virginia.

These are the number of hijackings (Figure 10) going back to 1961 when the first one for the United States occurred. You can see only a few until 1967, and then in 1968, a very rapid increase. It peaked out at 40 in 1969, with 82 percent being successful. We've started a downward trend. Unfortunately, as of today, the total for 1972 is 17 hijackings. The threat has totally changed since November 1971 when Air Canada had a hijacking attempt. A man planned to parachute out of the plane, but he was not as prepared as he thought he was. The parachute was wrapped up in a package well tied with string. When he was ready to bail out, he couldn't untie the string. The thoughtful captain offered the fire axe to cut it and, needless to say, he got close enough to lay the fire axe on the man's head, which put him out of commission. Shortly thereafter, on Thanksgiving eve, "D. B. Cooper" successfully bailed out over the Pacific Northwest. The FBI is still looking for him. The feelings are that he may yet be found in the wilds along the Washington-Oregon border. Since the "D. B. Cooper" incident, 11 out of 21 hijackings have involved extortion attempts or demands for money. So far, only two people have been successful. One was "D. B. Cooper" and the other a man who a few weeks ago went to British-Honduras.

Figure 11 is based on an FBI Report and shows successful prosecutions. Last Friday, LaPointe, who bailed out in the Denver area in early April (only about a month and a half ago) was sentenced to 40 years in Federal Court. I don't think the sentence of 40 years is as dramatic as the fact that he was tried, convicted, and sentenced in such a short time frame which is very encouraging.

President Nixon, after the Las Vegas bombing said, "We shall keep our airports, airways, and air travelers safe (Figure 12), and this is really what we are trying to do. As a result, FAA has issued Federal Aviation Regulations (Figure 13) which require compliance by the air carriers. These are the heart of the security program.

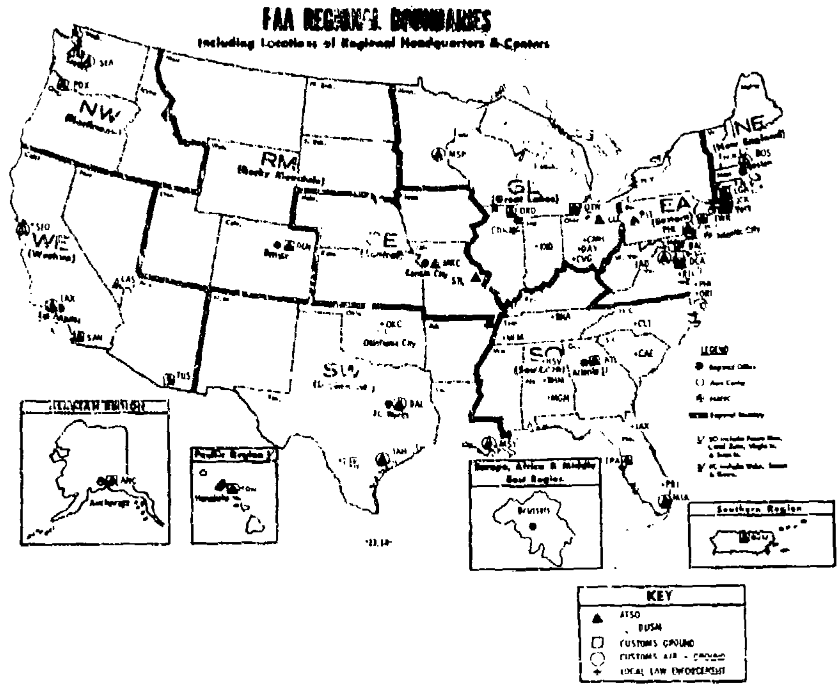
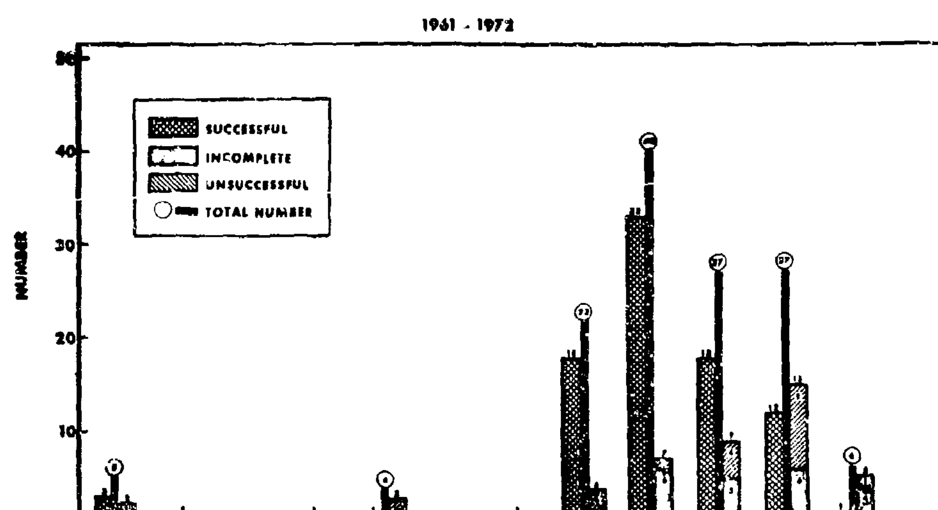
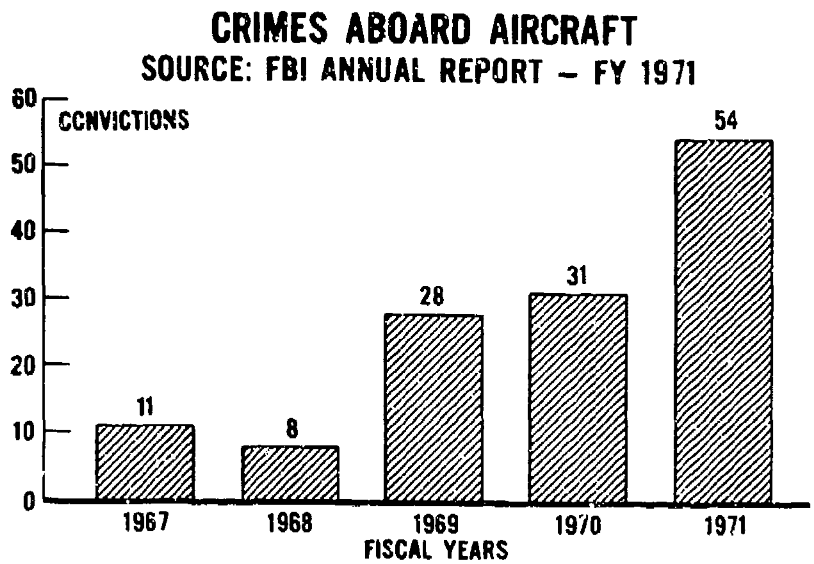


Figure 9. Federal Aviation Administration Regional Boundaries



YEAR	1961	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72 JAN	'73
% SUCCESSFUL	60	100	-	100	25	-	100	82	82	67	44	17	

Figure 10. Hijackings--U.S. Registered Aircraft



FY 1971	CONVICTIONS	54	2 LIFE SENTENCES
	SENTENCES	90 YRS	ACTUAL, SUSPENDED & PROBATIONARY
	FINES IMPOSED	$3600	
	FUGITIVES LOCATED	7	

Figure 11. FBI Chart on Crimes Aboard Aircraft--FY 1971

OUR AIR TRANSPORTATION SYSTEM FACES A NEW THREAT - EXTORTION

WE MUST NOT BE INTIMIDATED BY SUCH LAWLESSNESS

- **MOBILIZE ALL APPROPRIATE SECURITY FORCES AND RESOURCES UNDER OVERALL COMMAND OF SECRETARY OF TRANSPORTATION**
- **FARs FOR AIR CARRIERS WILL TAKE EFFECT AT ONCE**
- **FINAL RULEMAKING GOVERNING AIRPORT OPERATORS WILL BE EXPEDITED**

WE SHALL KEEP OUR AIRPORTS, AIRWAYS AND AIR TRAVELERS SAFE

PRESIDENT NIXON
MARCH 9, 1972

Figure 12. The President's Statements on the Extortion Threat

Somebody once asked, "How do you identify a hijacker?" Very easily (Figure 14). He's obviously the suspicious guy with the beard, the cigar, and the live chicken under his arm. The real tip off is the two carrots screwed into his ears. One of the Customs Security Officers during the Sky Marshall Training Course got up and asked this particular question. Thanks to Al Turner, a Treasury Department instructor, I have learned how to identify a hijacker.

Airport operators also have security regulations (Figure 15) applying to them. Many of you working in the local law enforcement area may become involved in this phase of the security program.

Bombs and sabotage threats are still of concern (Figure 16). This Air Security Bulletin has the guidance and procedures to help protect airports and terminal buildings.

When we talk about magnetometers, nobody has mentioned yet how the courts consider their use. In February 1972, in an opinion based on an occurrence at National Airport, the court (Figure 17) said that search by a magnetometer is justified and not unreasonable and a search is a compelling necessity to protect the lives of passengers.

Secretary Volpe has said only last March (Figure 18), when speaking to a group of airline presidents, "The resources of DOT and forces and resourcefulness of the Federal Government are committed to the conquest of air piracy, criminal extortion, and threats of sabotage. It is a job we must do together--government and industry, labor and management--with absolute dedication to unqualified success for total safety and security. We will not be intimidated." Secretary Volpe is a man who means what he says and is very dedicated to this program.

I would like to leave you with another safety message to show that the Department of Transportation is concerned about your welfare and protection in areas other than aviation. "Drive carefully. You and your vehicle may be recalled by the Maker."

AVIATION SECURITY - AIR CARRIERS - PART 121 FAR, FEBRUARY 29, 1972

1. ADOPT AND PUT INTO USE A SCREENING SYSTEM
2. PREPARE AND SUBMIT SECURITY PLAN
3. CONDUCT SECURITY INSPECTION ON RECEIPT OF BOMB THREATS
4. NOTIFY FAA IMMEDIATELY OF AN ACT OR SUSPENDED ACT OF AIR PIRACY

AVIATION ADVISORY CIRCULAR MARCH 14, 1972

AIR SECURITY BULLETIN 72-1, MARCH 6, 1972

MINIMUM ACCEPTABLE PROCEDURES TO:

1. PREVENT OR DETER CARRIAGE ABOARD AIRCRAFT OF ANY EXPLOSIVE OR INCENDIARY DEVICE OR WEAPONS IN CARRY-ON BAGGAGE OR ON OR ABOUT THE PERSON OF PASSENGERS
2. PREVENT OR DETER UNAUTHORIZED ACCESS TO AIRCRAFT
3. ASSURE BAGGAGE IS CHECKED IN BY A RESPONSIBLE REPRESENTATIVE OR AGENT OF THE CERTIFICATE HOLDER
4. PREVENT CARGO AND CHECKED BAGGAGE FROM BEING LOADED ABOARD AIRCRAFT UNLESS HANDLED UNDER APPROVED SECURITY PROCEDURES

Figure 13. FAA Regulations for Air Security

Figure 14. Hijacker--Dead Giveaway

AVIATION SECURITY - AIRPORT OPERATORS - PART 107, FAR -3/16/72

1. IMMEDIATELY ADOPT AND PUT INTO USE FACILITIES AND PROCEDURES, DESIGNED TO PREVENT OR DETER PERSONS OR VEHICLES FROM UNAUTHORIZED ACCESS TO AIR OPERATIONS AREA.
2. SUBMIT PROGRAM FOR APPROVAL COVERING:
   a. MASTER SECURITY PLAN IDENTIFYING AIRPORT AREAS, DEGREE OF SECURITY THEREIN AND PROPOSED IMPROVEMENTS
   b. IDENTIFICATION OF AUTHORIZED PERSONS AND GROUND VEHICLES.

Figure 15. Airport Operators Security Regulations

AVIATION SECURITY - BOMB/SABOTAGE AIR SECURITY BULLETIN 71-2, OCTOBER 22, 1971

GUIDANCE TO: AIRPORT MANAGEMENT, AIR CARRIER PERSONNEL AND OTHERS RESPONSIBLE FOR DISASTER CONTROL

PROVIDES FOR: EMERGENCY RESPONSE PROCEDURES TO BOMB THREATS AND BOMB INCIDENTS

PROCEDURES FOR: PRE-THREAT, BOMB THREAT ACTIONS, POST-THREAT REACTIONS, SEARCH AND DISPOSAL TRAINING, TEST EXERCISES, REPORTS, NEWS RELEASES

RESPONSIBILITIES FOR: PLANNING, COORDINATION AND ACTION

Figure 16. Bomb/Sabotage Air Security Bulletin 71-2

AIR PIRACY AND ITS THREAT TO NATIONAL AIR COMMERCE IS A WELL KNOWN DANGER. GOVERNMENTAL INTEREST IS SO OVERWHELMING AND INVASION OF PRIVACY SO MINIMAL, THAT SEARCH BY A MAGNETOMETER TO DISCOVER WEAPONS AND PREVENTING AIR PIRACY IS FULLY JUSTIFIED AND NOT UNREASONABLE.

SUCH A SEARCH IS MORE THAN REASONABLE, IT IS A COMPELLING NECESSITY TO PROTECT ESSENTIAL AIR COMMERCE AND THE LIVES OF PASSENGERS.

FOURTH CIRCUIT COURT OF APPEALS
U.S. vs EPPERSON
2/7/72

Figure 17. Appeals Court Decision on Magnetometer Search

THE RESOURCES OF DOT AND THE FORCES AND RESOURCEFULNESS OF THE FEDERAL GOVERNMENT ARE COMMITTED TO THE CONQUEST OF AIR PIRACY, CRIMINAL EXTORTION AND THREATS OF SABOTAGE

IT IS A JOB WE MUST DO TOGETHER - GOVERNMENT AND INDUSTRY - LABOR AND MANAGEMENT - WITH ABSOLUTE DEDICATION TO UNQUALIFIED SUCCESS FOR TOTAL SAFETY AND SECURITY

WE WILL NOT BE INTIMIDATED

JOHN A.VOLPE
SECRETARY OF TRANSPORTATION
MARCH 10,1972

Figure 18. Secretary of Transportation Statement on Air Crimes

X-RAY EQUIPMENT AND BOMB TRANSPORTATION EQUIPMENT

By: Ralph L. Miller, U.S. Army Picatinny Arsenal

I would like to describe the work being done at Picatinny Arsenal in support of the Army Explosive Ordnance Disposal (EOD) Program. In order to better understand our work, a few words should be said about EOD. Most of you are aware that there are some 60 EOD detachments stationed throughout the United States. Last year, about 75 percent of all the Improvised Explosive Device (IED) incident reports in the United States were answered by these personnel. Consequently, we must provide these personnel with the best capability possible so that they can do their job more effectively in response to reported IED incidents.

Figure 1 shows the equipment that is on hand for one Army EOD detachment. As you can see, there are three trucks plus the support equipment. All of this equipment is necessary for any assigned mission. In discussing any program in this area, it is obvious that equipment use, weight, shape, and other similar considerations are of utmost importance. Simply stated, we have to look at the equipment and the components from the standpoint of size and mobility. That is to say, can two men, as a minimum, move this equipment in order to accomplish a given function?

In November 1970 we were asked to provide certain selected equipment to various EOD units in this country for evaluation. Test results would determine useability by Army EOD units throughout the world. Evaluation allowed use of the equipment in actual reported incident cases, if any, during the test period. Under this request, we were told to provide 25 X-ray units that had a capability of evaluating suspect devices in two forms: (1) the attache case type, and (2) the pipe bomb type.

The best way to get involved in a program like this is to see first what is commercially available. From there, you proceed to isolate equipment which appears to be adequate--the ones which probably will survive in the EOD environment--and eventually arrive at decisions relative to selection and choice.

We were also asked to provide two image intensification systems for evaluation to determine whether these could be used in our support to the Secret Service. In addition, we were asked to provide four fluoroscopic devices to the field, so that they could be evaluated to see whether these could be used in our support to VIPs. In other words, rather than having an image intensification system, a fluoroscopic system could be carried and put into position by two personnel, and EOD evaluations could then be performed.

The image intensification system, as most of you know, is a Norelco unit. It was the unit that we, in conjunction with Phillips, put together for this program. We bought three of these units (Figure 2). Basically, there are three major components: the intensifying screen, the monitoring unit, and the storage tube. We have to make this equipment as lightweight as possible so that two men, or a maximum of three, will be able to use this in EOD. There is no guesswork in positioning the X-ray since this is already set. The electronic eye automatically fires the unit. The camera is placed in back of the arrangement. Of course, after it is set up, you can check bags both automatically and manually. Simply, what is happening is that we are putting on a screen a view of the inside of a suspect device.

The fluoroscopic unit that was decided upon was the medical X-ray, which was already available (Figure 3). Its capabilities appeared to meet the needs of our Army EOD personnel. The equipment was designed to be para-dropped in war zones for use by medical personnel. For this reason, it was obvious that this equipment was meant to withstand quite a jolt. For those of you who are aware of our program, this is important. What we did was to make two modifications to the existing equipment which enabled us to meet our requirements. By changing one capacitor we got an add-on use cycle. Thus, the heat buildup that occurred in the initial units was no longer a problem. We also added ancillary equipment to this particular package which made it possible for two men to handle the entire job. Figures 4, 5, and 6 show, respectively, the tube head, power source, and control of the equipment. We decided to go with the 4- x 5-inch picture setup during the evaluation period, simply because of the size of the developers with the 8- x 11-inch.

Last year, in November, I attended the American/British/Canadian Tripartite EOD Conference at Indianhead, Maryland, and discovered a piece of equipment in their laboratory which, I was told, was made about 4 or 5 years ago by a commercial company. I was informed that the equipment was never promoted and, therefore, no demand existed for it; but, it was an item of interest to those at the laboratory. Inspection of the equipment and subsequent inquiries to the company showed that a 12-pound developer could be made for Army EOD use. Now, we could go to the larger film. Everybody wanted a larger capability from the film standpoint. So, based on that and as we go further into this program, size will be increased to 8- x 11 1/2-inches.

Figure 7 shows an operational step in the detection process. The distance involved would be about 20 feet. The man standing there would take the picture. The evaluation in the field did, in fact, lack a piece of equipment. We found that we had two problems. The tube itself contained hexafluoride gas. By not putting the connector back on properly, the hexafluoride gas leaked out. We found this out after an EOD squad called us and asked for replacement gas.

The other problem was the battery, a fast rise type. Unit instructions indicated that charging time should not exceed 8 hours. We went through eight batteries in this program. Only two were dropped. The other six were overcharged. So, we do have a problem in this area, and we can resolve it.

Another thing we are going to do is to extend the cable from 20 feet to about 80 feet. The tube-head is the only thing that is in the area of the IED. Therefore, all actions would be eliminated from the IED, with the exception of the positioning of the film. In other words, we are reducing stay-time around the hazardous device. The fluoroscopic capability that we mentioned earlier adapts to the medical X-ray capability of visually looking inside a unit or a suspect package. Refer to Figures 8, 9, and 10. This is the same tube-head that we fielded. We are trying to make a 12- x 14-inch port where the fluorescent screen would be. A person could then view the packages. This is a two-man operation. The individual who operates the equipment also sets the package. Radiation is a hazard, therefore, the person operating this equipment should be careful.

Now, after one has put all of his equipment in the field, he can look at his design. One thing we found out after getting this equipment in the field was that if you can isolate the important components, you can look at a lot more. For example, by taking the package, moving the screen and making shielding adjustments, the lead glass for the viewing port could be cut to about 8- x 10-inches. In fact, the entire viewing area can become anything you wanted by moving the screen. We are going to look at a package which is probably a 24- x 28-inch envelope. In this way, we will be able to look at an entire suitcase as against an attache case. We finished our prototype model, and this is what we are recommending. When the user representative comes to us and requests these components, we are going to recommend the new design.

Question and Answer Period

Q. Did you have any idea what the dose levels are?

A. Yes, we do. Each piece of equipment that we put out in the field must have the approval of the Army Environmental Hygiene Agency. Dosage cannot exceed the allowable limits, and I believe that is now 10mR. What we have to do is provide sufficient protection to the individual on one side of the screen so that he receives no more than 10mR per quarter on that side.

Q. Could you define this dose--at what period of time and at what distance?

A. Well, we know what is coming out. What we tried to do was to find out, based on the different thicknesses, what is coming through the lead glass. So, based on what we thought was coming through the lead glass, we built our first prototype and we gave it to the Environmental Hygiene Agency. They will tell us whether or not a person operating this equipment--I believe the time period is about 1,000 seconds--will receive the allowable quarterly dosage, which I understand is 10mR.

Q. In a thousand seconds you will give 10mR. Is that what you are saying?

A. We will not exceed 10mR in 1,000 seconds, which is the allowable time for that man to sit there in a quarter.

Q. And then you have a new man every sit down?

A. Right. In other words, that is the way we do it now because of our human factors people. They tell us that an individual can only sit there for a period of about 5 minutes. Changes have to be made at 5-minute intervals. It's a three-man operation. But 5 minutes is a lengthy exposure time. It takes only 5 seconds to look at any bag to see what's inside.

Bomb Transportation Equipment

The second part of the program has to do with bomb transportation. As soon as a problem is identified, the EOD men either take on-the-spot action, or they move the item to a safe location for the performance of their tasks. Last year we were asked to evaluate bomb transportation. In order to understand this problem, one must have some idea of the explosion phenomenon that occurs inside a container. For example, what are the effects on the environment when five sticks of dynamite explode inside a container?

What we did was to put the necessary load cells in a test container (Figure 11) so that we could read the pressures coming off. We placed paper gauges at different elevations. They are not very accurate, but they can tell you when various psi pressures are reached. So, as far as paper gauges go, we know basically what is happening. Most people feel that when an explosion occurs a straight line blast wave results. What we wanted to do was to find out what kind of pressure was coming over the lip and straight at the gauge. Motion pictures were taken of each explosion at 6800 frames per second and slowed down for detailed observation and study. We then took a print of each shot to determine the basic data needed for further evaluation.

We were asked last year to see what could be done in regard to transporting these items from the incident site to the safe area. In answer, we instituted a two-phase program. In phase one, we obtained a commercially available item (Figure 11) and removed all accessories, since these were not needed in our program. We then added the attachments needed to hook this up to a standard 2-1/2 ton vehicle. We added air brakes for compatibility with the truck. This was, simply, a container within a container. The requirement was that it would be able to withstand a 20-pound shot of either a military or commercial explosive. In advance of receiving these units, we bought two each of the inserts, and then started our test program to determine the maximum limit. In other words, rather than just saying that it was 20 pounds, we wanted to know precisely what it was. In that way, as far as Army use and our technical data bank are concerned, we would know precisely what the trailer would do. We exceeded the elastic limit of the insert in the first 5-pound shot. So, from a reuse standpoint (Figure 12), it's not too good. However, that's strictly from the elastic limit standpoint. Our Army EOD Group at Redstone Arsenal has been firing into one of these light containers for over a year (15 sticks a shot) and it hasn't failed yet.

What we have to do now is to determine where the tradeoff between fatigue and the elastic limit is. Of course, there would be a barrier material (sand) in the container. The unit will weigh about 7,000 pounds. It's not too expensive. I think the price would be about $5,000. Provided the rest of the tests go as well as they have so far, we will be fielding two of these units prior to the coming national conventions. They will go to the EOD units that are going to support the Secret Service in Miami.

In phase two we recommended a total containment capability. We foresee a capability where there will be no extraneous, exterior blast to the container itself. For quite some time now Los Alamos has been testing small quantities of military explosives to find out what the best shape of their explosives will be versus other materials. They set up a capability where they actually put the materials inside a sphere, drew a vacuum on the sphere, and fired the shot. They have successfully contained over 35 pounds of military explosives in this way. The sphere is 6 feet in diameter, and the wall is approximately 1-inch thick. Probably, the best part of such a system is that not only can you produce a vacuum to suppress the explosion, but by creating another vacuum, the sound of the explosion can be suppressed. In other words, suppose we had something like this in this room and we had an IED. If we moved the suspect device into the next room and exploded it, you wouldn't hear it in this room. This is the direction we would like to see containment go for the Army EOD. Of course, there are technical problems. How can you create a vacuum without destroying the seal that's going to keep the explosion inside? We expect that prior to September this will be resolved.

We hope to receive sometime in October our unit from LASL so that we can verify the testing that has been done on military explosives at Los Alamos. The unit will weigh about 10,000 pounds and will cost about $20,000. The trailer will be a standard military trailer and will be able to be hooked up to the vehicles that are available to the Army EOD.

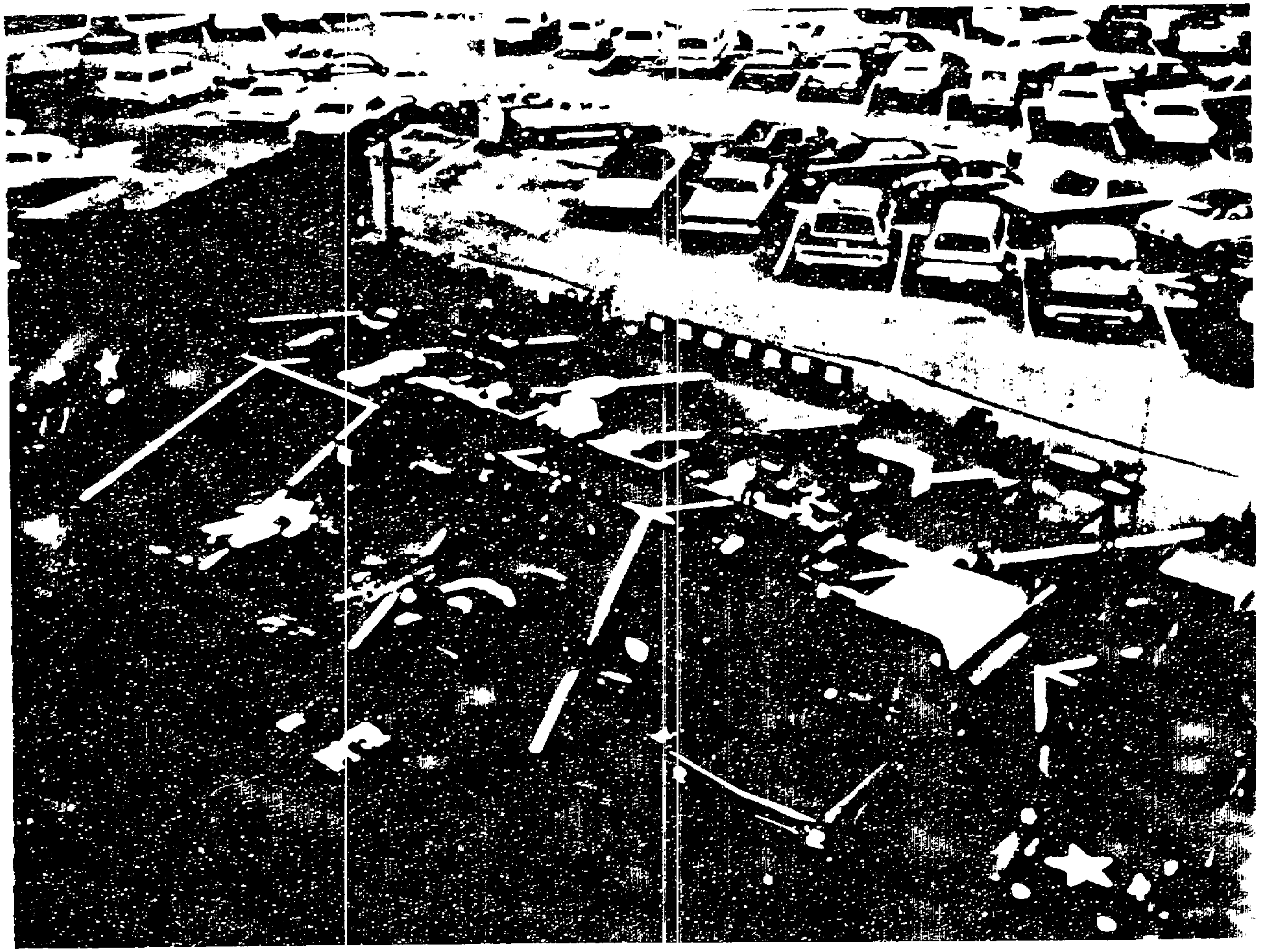


Figure 1. Equipment for Army EOD Detachment

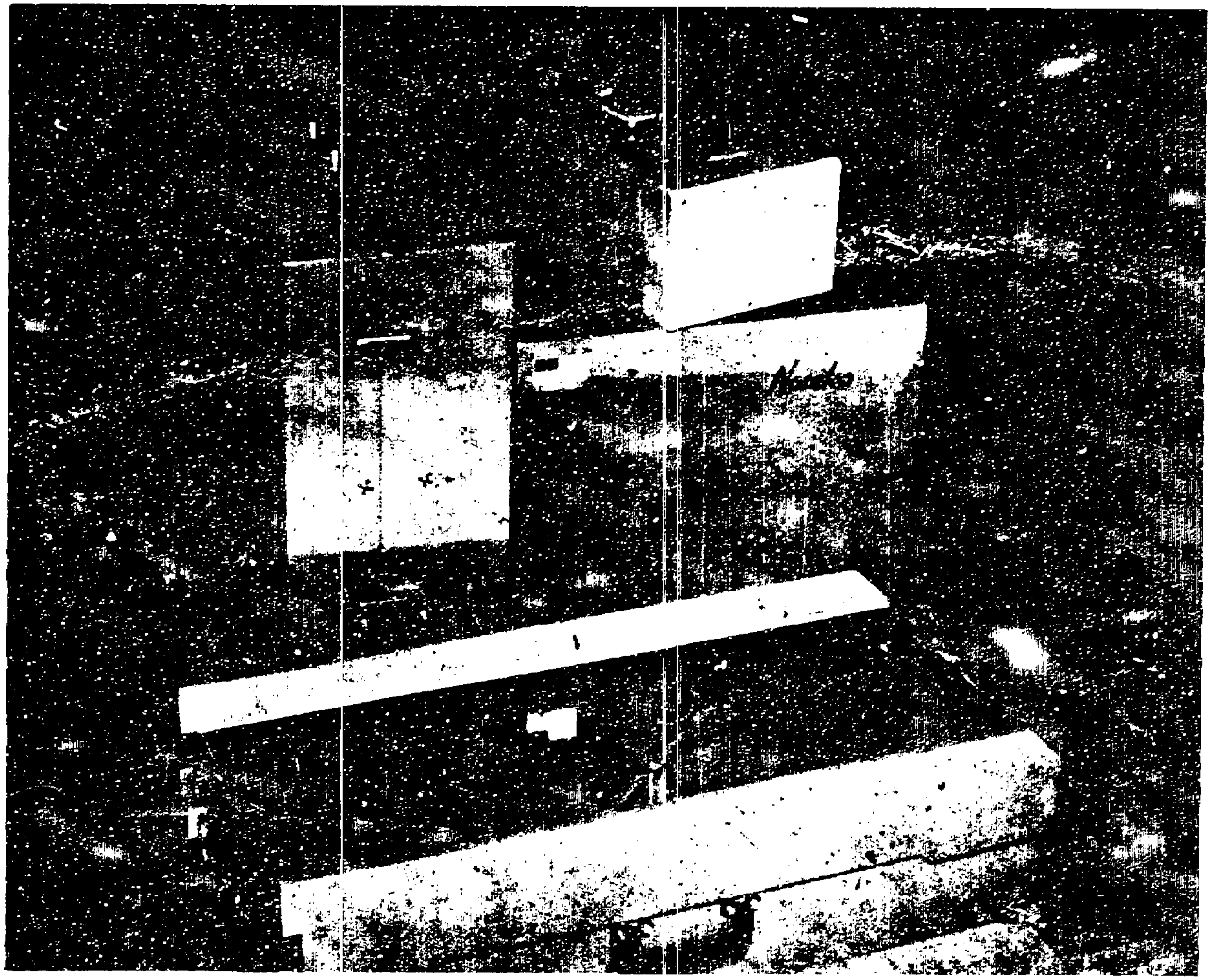


Figure 2. Norelco Image Intensification Equipment

Figure 3. Medical X-Ray Equipment

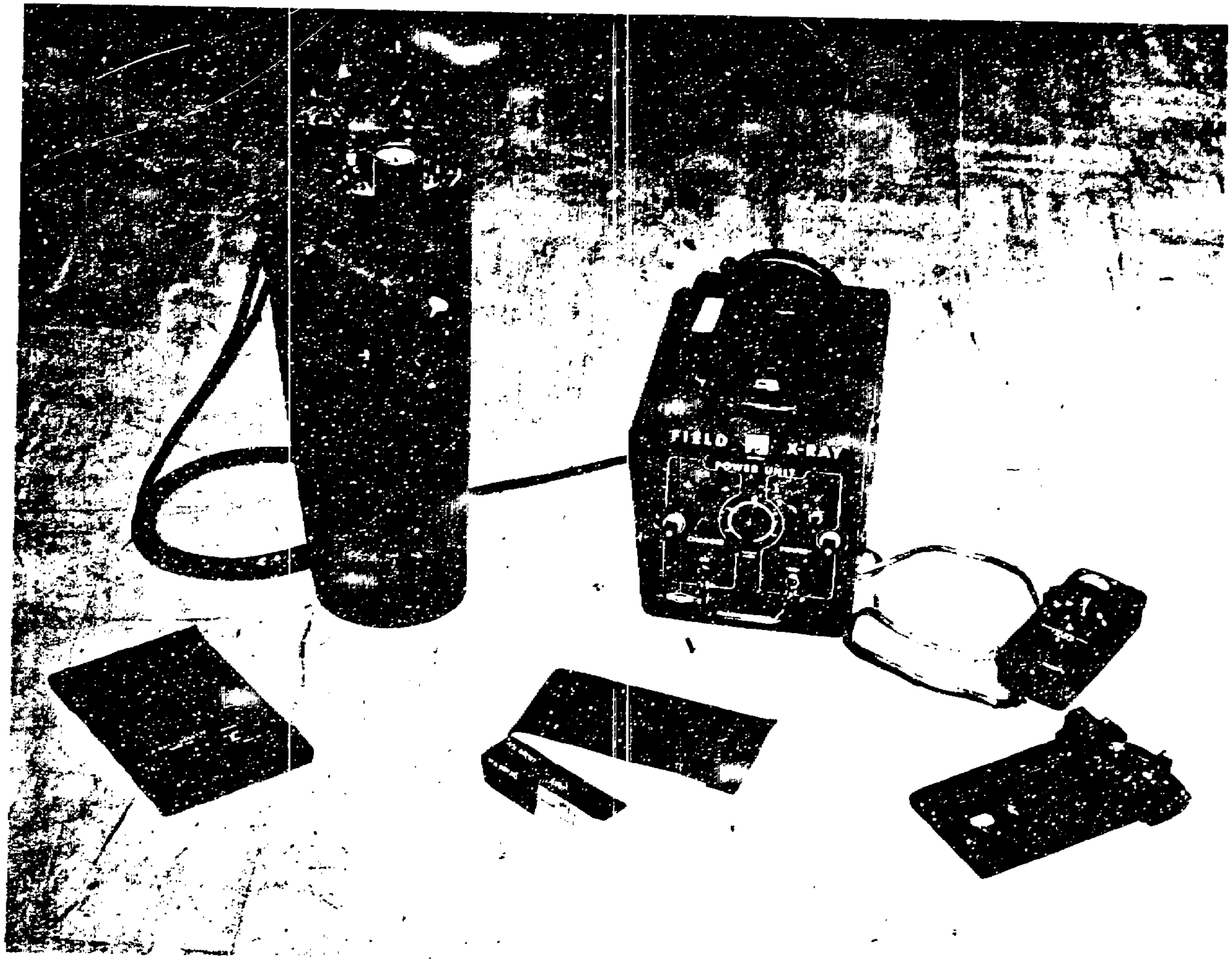


Figure 4. X-Ray Equipment--Tube Head, Power Unit, and Controls

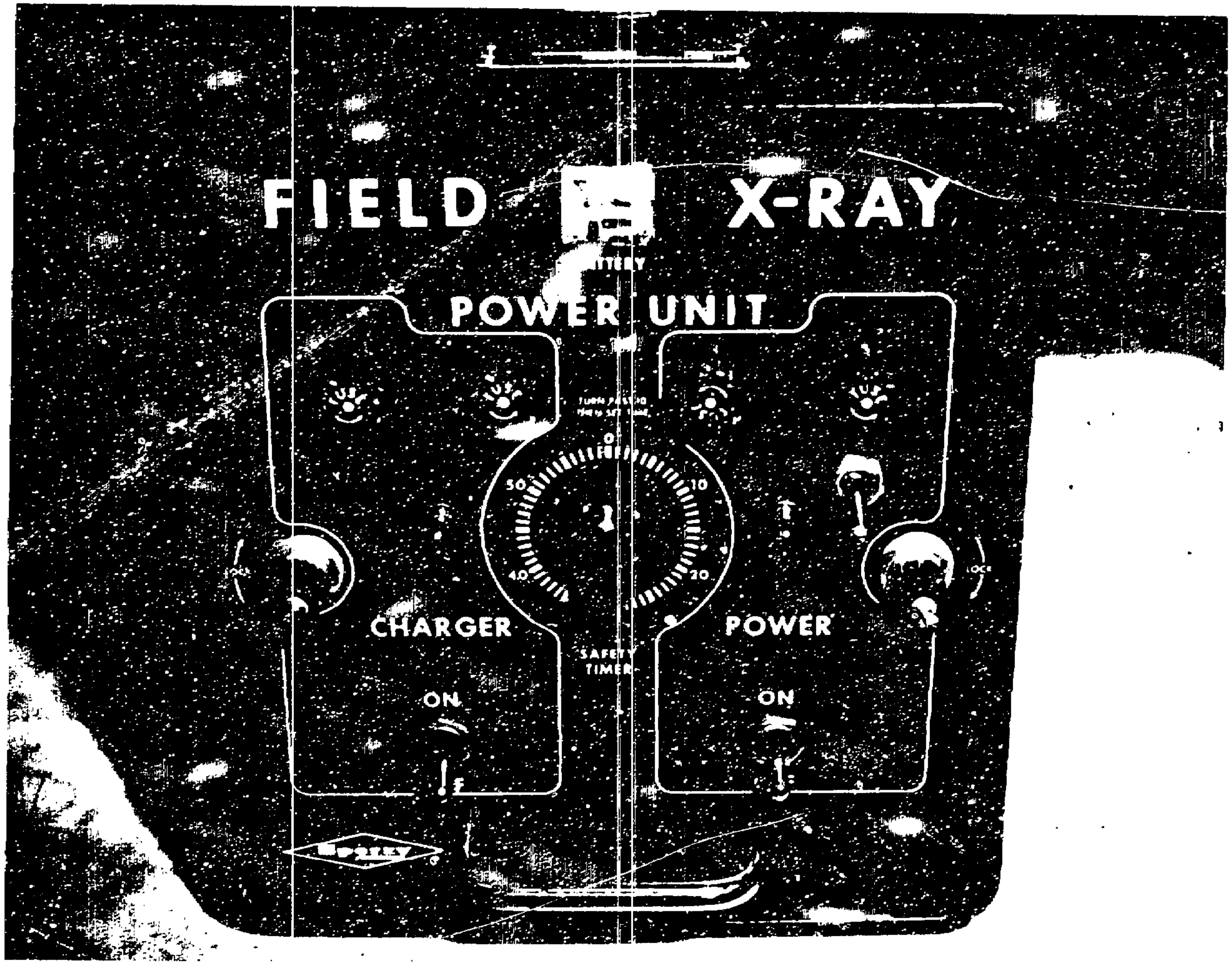


Figure 5. Close-Up--Field X-Ray Power Unit

Figure 6. Close-Up--Field X-Ray Control Unit

Figure 7. Field X-Ray--Operational Setup

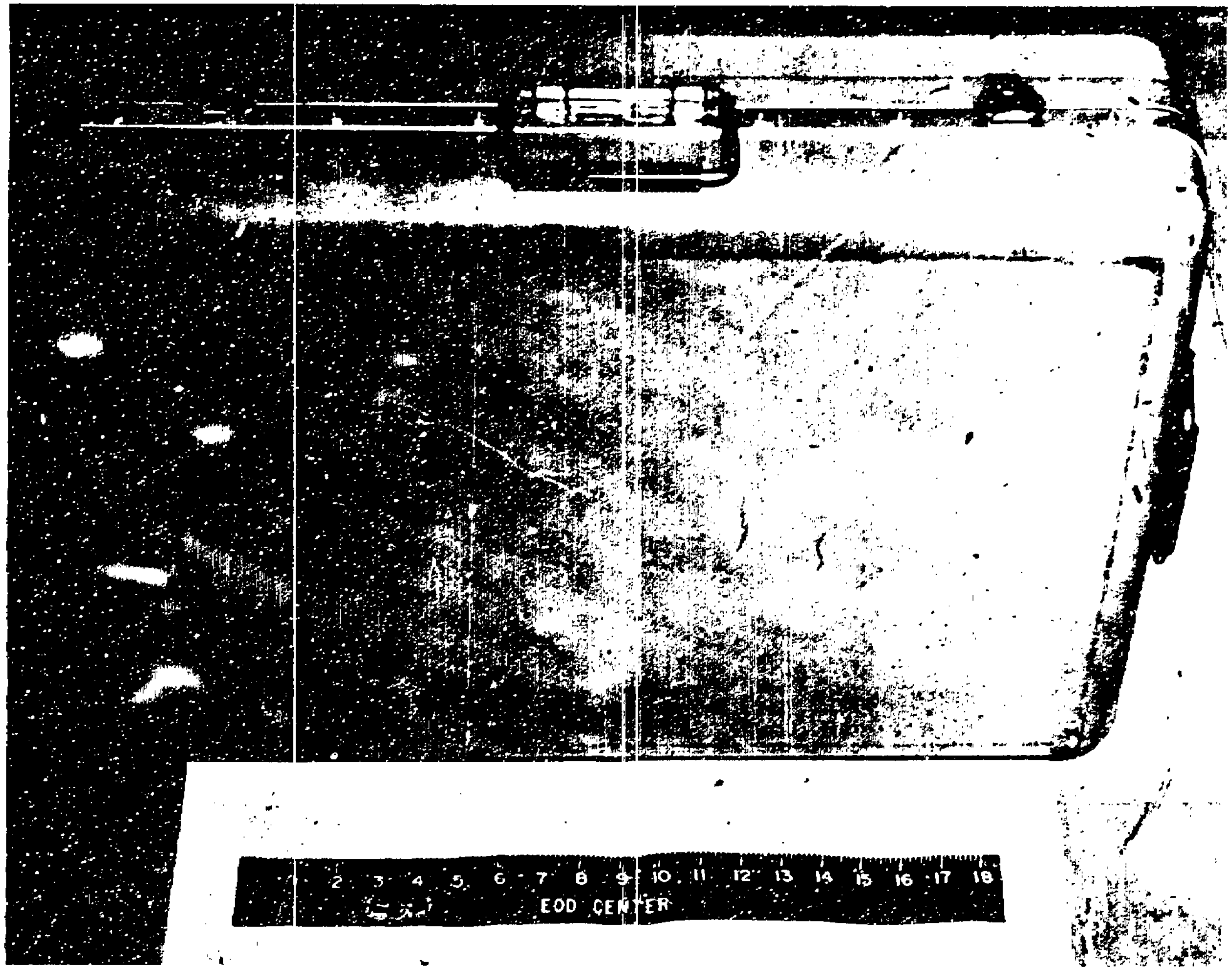


Figure 8. Fluoroscopic Screen Carrying Case

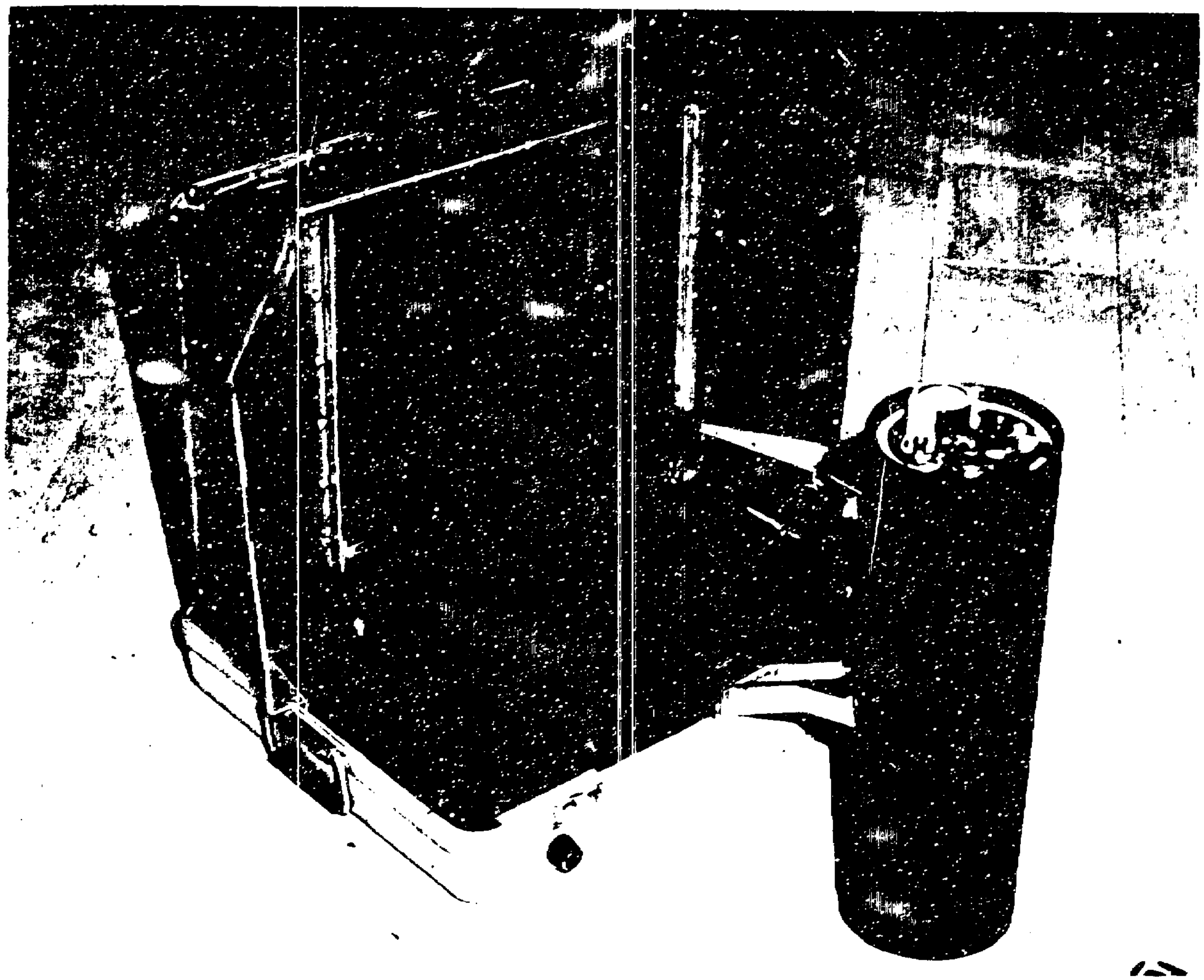


Figure 9. Fluoroscopic Screen Case With Tube Head

Figure 10. Fluoroscopic Screen Operational Setup

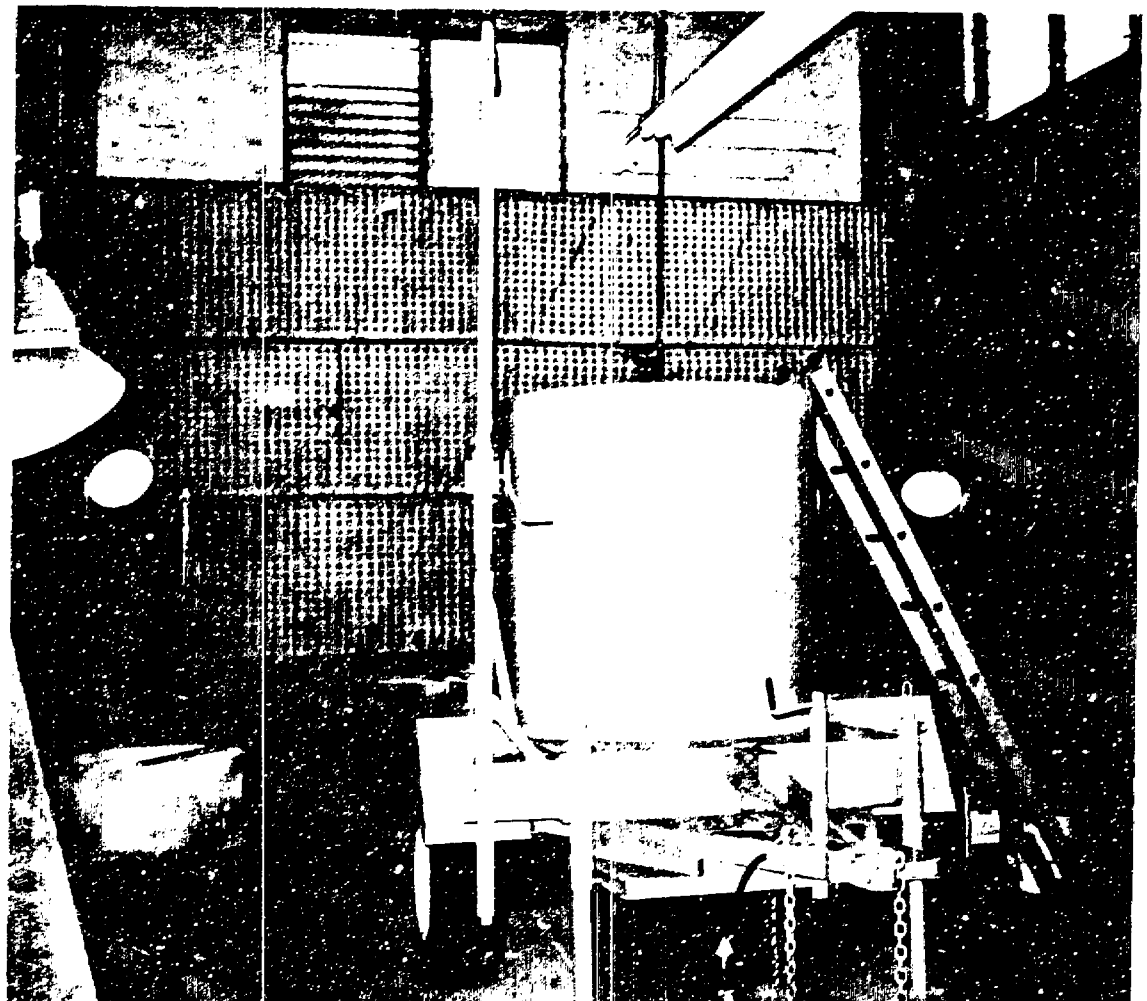


Figure 11. Bomb Container Without Accessories

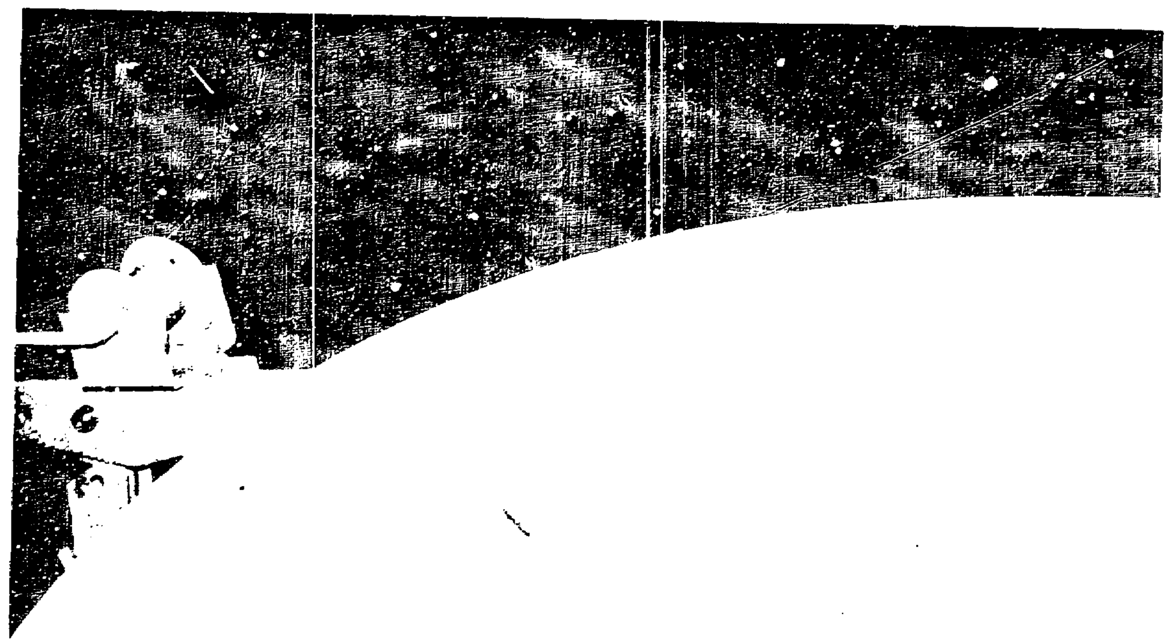


Figure 12. Close-Up--Bomb Container

X-RAY COMPONENTS WITHIN THE INTEGRATED ACCESS CONTROL SYSTEM

By: Lawrence J. Nivert, Intrusion Detection Division, CM/CI Department, USAMERDC

For the past three years the Mobility Equipment Research and Development Center (MERDC) has been developing X-ray inspection systems for the detection and classification of hand weapons. The program has been carried out within the guidelines established for the Protection of Public Figures Program, and the radiographic systems are intended for use in what is called the Integrated Access Control System (IACS).

Conceptually, the IACS is an array of several different types of weapons detection devices which will be employed in controlled access areas for the examination of both personnel and hand carried items, such as briefcases and purses. Both a personnel and a package inspection X-ray unit are currently undergoing evaluation tests at MERDC.

The primary emphasis within the IACS has been placed on the development of a covert personnel X-ray system. This particular configuration employs an electromagnetic device as a predetector so that only those individuals who have a fairly high probability of possessing a weapon would be X-rayed. This technique minimizes the dosage received by the general population as well as yielding the obvious benefits of a surreptitious measurement. An alternative to the covert system would be the X-raying of individuals with their knowledge and consent. While the present personnel system could easily be adapted for such usage, a significant reduction in whole body radiation dosage could theoretically be achieved by employing the flying spot approach. This type of approach could result in a more compact and safer system and avoid possible legal complications. In areas where it would be completely unfeasible to operate a personnel system, a shielded package inspection unit would be employed for hand carried item inspection.

In defining the present version of the personnel X-ray system, several system concepts governed the engineering approach. Since a covert measurement was desired on individuals who would be in motion, data acquisition could not take longer than 1/30 of a second without introducing an unacceptable degree of blur in the image. It was desired to keep the whole body radiation dose received by an individual walking through the system on the order of one mR. This would represent about the same dosage one would get from natural background sources in 3 to 4 days. A primary constraint on the overall physical size of the system was the need to view the torso and extremities (to below the knees) of a 6-foot tall individual. Finally, in order to minimize the dosage to the general population, an electromagnetic predetector would be interfaced with the X-ray unit so that only those individuals who have a high probability of a weapon on their person would be X-rayed.

Figure 1a presents a block diagram of the personnel system. The condition for the initiation of a radiographic inspection is the simultaneous occurrence of two events. The electromagnetic predetector must indicate a quantity of metal above a certain threshold level, and a position sensor, at the present time simply a switch, must indicate that the individual is at the proper location for the geometry of the X-ray source and collecting optics.

Once these two events occur, the operation of the system is completely automatic. A lead shutter in front of the X-ray source will open for approximately 1/15 of a second, and the X-rays will pass through the suspected target, be collected by the optics and video pickup, and returned to the interface console. The visual information is stored on a video tape recorder and then continuously displayed on a television monitor for operator interpretation.

One possible physical configuration which is now being implemented to accomplish the data acquisition is shown in Figure 1b. An individual would enter the revolving door, which is made entirely of wood and plastic, from the left and pass between the two columns of the electromagnetic detector. If the predetector indicates an excessive quantity of metal, a radiograph would be initiated when the person has reached the position marked "revolving door" in the figure. The X-ray shutter would fire, and the radiation would pass through the door and suspected target and impinge on an X-ray fluorescent screen. The screen acts as a transducer which converts the extremely short wavelength X-radiation into visible light. The light is collected by the optics and an image of the fluorescent screen is viewed by a TV camera. This information is then transmitted to the operator console for display and interpretation.

The X-ray source inclosure (Figure 2) contains a Balteau 300/5 unit. A single pulse of radiation is derived from the motion of a mechanical shutter which is composed of two overlapping lead leaves. In operation, two linear motors drive the separate leaves in opposite directions and at the center of their travel the openings overlap allowing the X-ray beam to be emitted.

Since the safety of individuals walking through the system is of paramount importance, each shutter leaf has been doubly interlocked. If power to the shutter drive should fail or if there were a mechanical failure of any type which did not allow the shutter to completely close, power to the X-ray tube head would terminate and the generation of X-rays would cease.

With the present hardware available the operating conditions for the source have been optimized at 300 kilovolts with 3ma tube current and 0.4 inches of aluminum filtration. The energy spectrum emitted by the source emphasizes the shorter wavelengths and is referred to as a hard spectrum. Even higher kilovoltages would be useful in obtaining

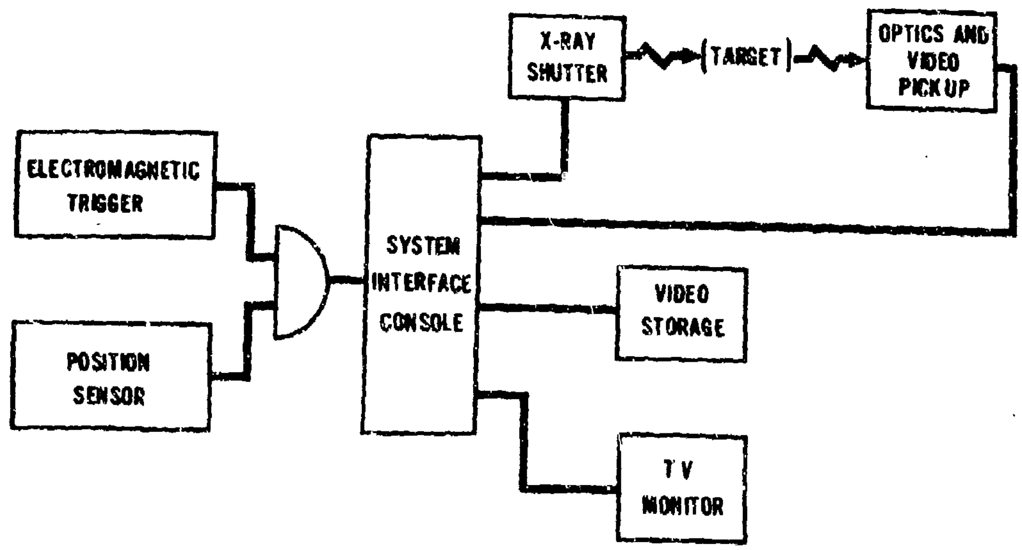


Figure 1a. Personnel X-Ray Block Diagram

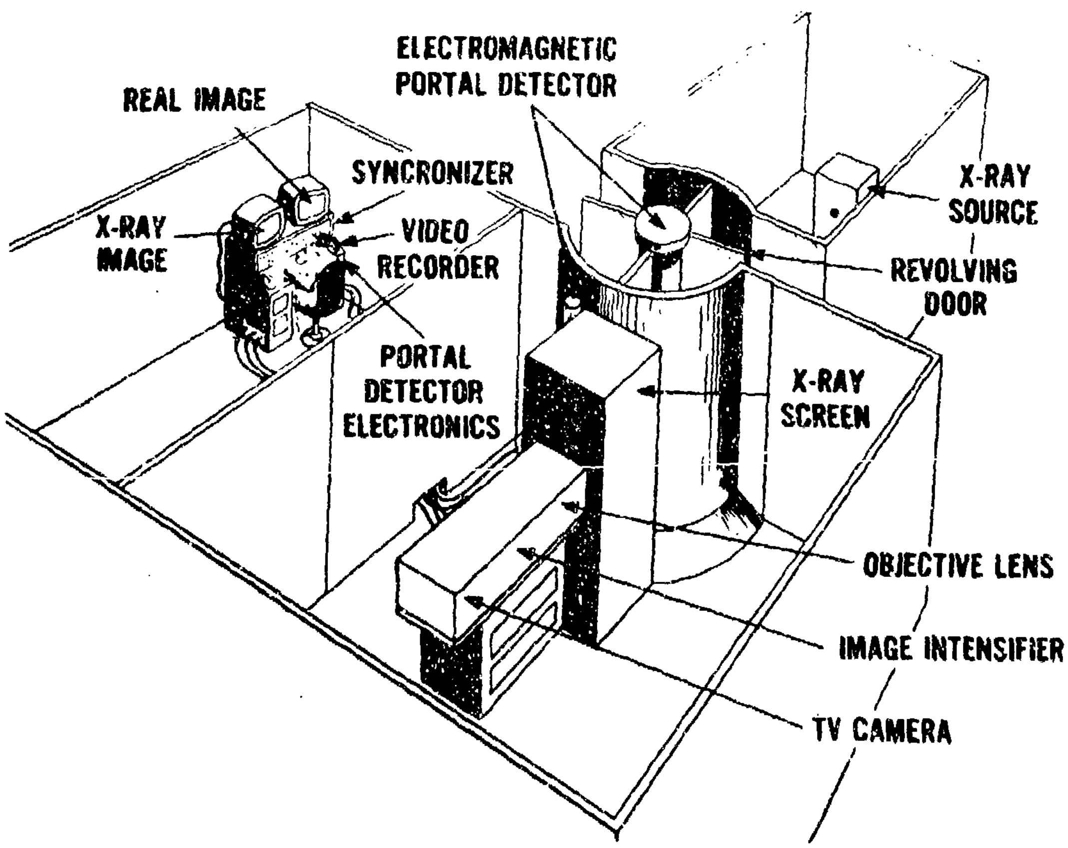


Figure 1b. Personnel X-Ray Configuration

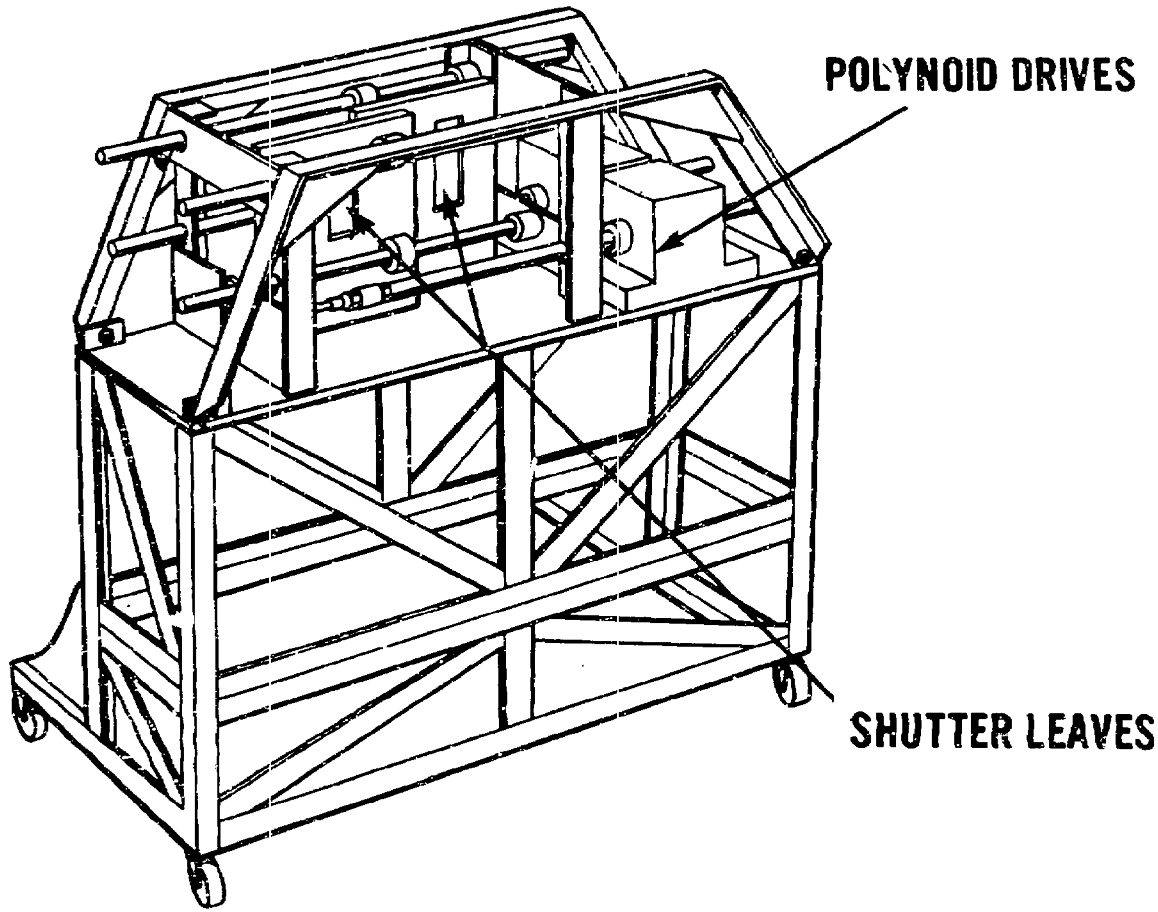


Figure 2. Leaded X-Ray Enclosure

the radiographic information because of the increase in contrast obtained between a steel weapon and human body tissue and because of the increase in transmitted energy in the thicker portions of the anatomy.

Figures 3a and 3b detail the individual components of the X-ray and optical ends of the system. In Figure 3a the X-ray source is shown firing through an individual with a hand gun on his chest. The high density metal in the weapon attenuates the X-ray beam more than the surrounding body tissue and then impinges on a Dupont CRONEX® fluorescent screen. The screen emits light with a characteristic P-20 curve in direct proportion to the intensity of the X-rays incident on it. The resultant radiograph is thus a shadow picture of the target which is exposed.

As can be seen from Figure 3b, the image on the screen is focused onto the input face of an image intensifier and the output of the intensifier is viewed by a television camera. The electro-optical hardware employed in the system is near the present limit of modern technology. The Angénieux objective lens has an 18 millimeter focal length with an f number of 1.5. It can focus the entire 8' x 3' screen onto the 40 millimeter diameter protocathode of the image intensifier at a nominal distance of 4 feet. This results in a much more compact system than would be possible if commercially available camera lenses were used.

An RCA 33085AP1 unit is the image intensifier for the system. The tube is spectrally matched to the output of the fluorescent screen for optimum response and has a luminescent gain on the order of 1.5×10^6. A magnetically focused device was chosen over an electrostatically focused tube primarily because of its higher gain and resolution characteristics and its lower inherent distortion. At the television camera, a silicon diode vidicon, which has a significantly higher sensitivity than the normal separate mesh videcon, is used.

At the present time no radiographs of personnel have been attempted with the personnel X-ray system. A Picker XR-100 phantom has been utilized to make some preliminary measurements. The phantom is composed of tissue equivalent plastic and by itself approximates an individual weighing nominally 160 pounds. In previous measurements which were made at Bendix, it was experimentally determined that by augmenting the abdominal region with 1-1/2 inches of water the phantom would then approximate a 185- to 190-pound target.

Typical operational results from the system are characterized by the data presented in 4a, 4b, and 4c. The first figure is a photograph taken directly from the output face of the image intensifier. Several targets are readily apparent on the phantom as well as the water augmentation in the region of the abdomen. It is evident that the hardest area of detection is in the abdomen. Primarily, this is the result of two separate effects, both of which are directly attrib-

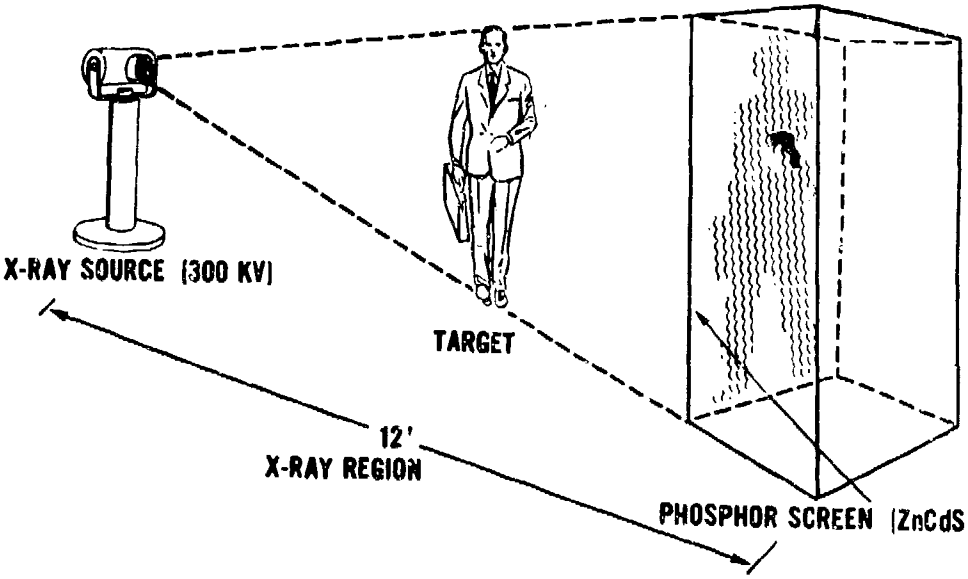


Figure 3a. X-Ray Region of the System

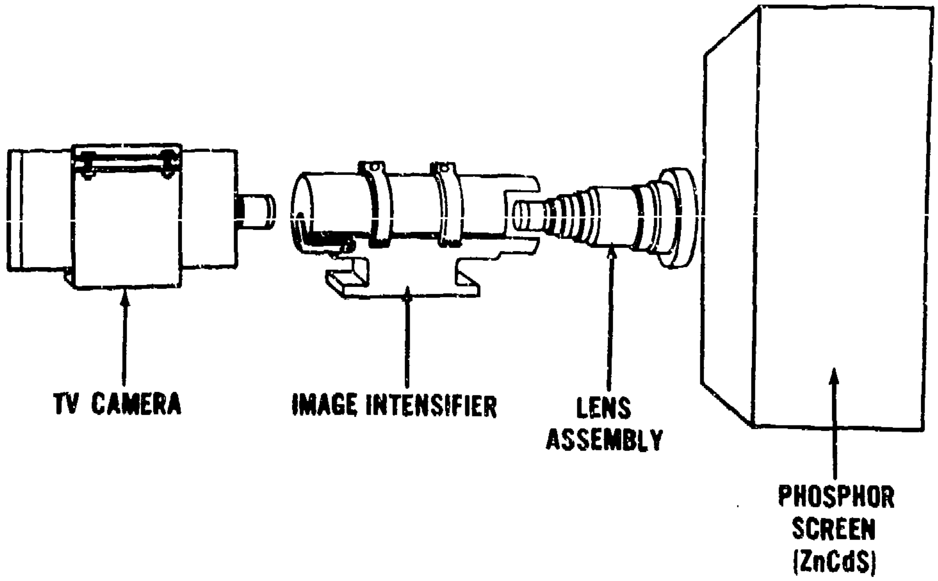


Figure 3b. Electro-Optical Region

Figure 4a. Direct Photograph From Output Face of Image Intensifier

Figure 4b. Phantom With No Water Augmentation

Figure 4c. Phantom With Additional Water

utable to the greater amount of water which the X-rays must penetrate. The penetration of X-rays is substantially reduced in this area due to the water, and secondly, a larger percentage of the radiation is scattered and reduces the overall contrast in the image.

The data presented in Figures 4b and 4c were actually taken from the television screen and represent what the operator would view on a real time basis. The first photograph is of the phantom with no water augmentation. All the targets are readily identified, even the weapon in the abdomen. The second photograph demonstrates the degradation in classification effectiveness that is introduced by the presence of additional water. Even with the direct output of the television monitor, it is extremely difficult to discern the weapon in the abdomen area. A secondary problem which is visible in both photographs is the saturation of the videc system in the highlight regions. The blooming is primarily at the target of the silicon diode vidicon and future work on the project will involve a search for a tube with at least the sensitivity of the silicon diode and a wider dynamic range capability.

As mentioned previously, the safety of individuals exposed in the system is of prime concern. Consequently, several series of dosimetry tests were performed utilizing various types of pencil dosimeters, thimble ionization chambers, and a Victoreen 444 ionization chamber with an integration capability. The average of the results of these tests are shown in Figure 5. The values obtained are somewhat higher than the actual absorbed dose due to the fact that the measuring devices were placed external to the phantom. Consequently, back-scattered radiation as well as the directly incident beam were included in the measurements. In future testing, a sectional phantom will be procured and thermoluminescent detectors will be used to make radiological measurements at the actual organ locations; this should provide a much more accurate map of the actual dose distribution and be of greater use in evaluating the potential hazards involved in the system.

The chart shown in Figure 6 gives some relative values for various X-ray dose levels. The maximum allowable whole body dosage for radiation workers is 100 mR per week or 5 R per year; this does not include the exposure due to medical sources. A very rough guess at the amount of radiation required to produce a noticeable change in Polaroid 3000 speed film is 5 mR. Note that the defining qualification here is the term noticeable. Any exposure will produce some density change in a photographic emulsion; however, for this to be visibly detected in a positive or transparency, the dosage must be at least 5 mR. The cumulative dose due to naturally occurring radioactive sources is on the order of 0.3 mR to 0.5 mR per day, while flying at relatively high altitude raises this number significantly. These figures simply serve as a perspective background for the 1.5 mR whole body exposure expected from the personnel X-ray system.

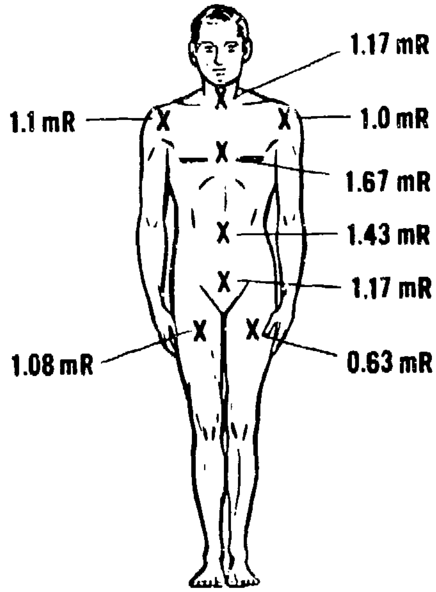


Figure 5. Typical Expected X-Ray Dose

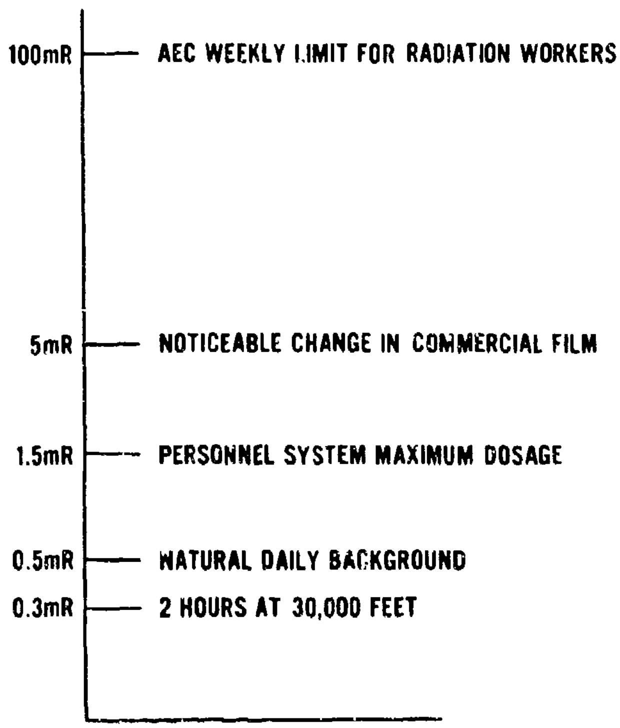


Figure 6. Relative Values For X-Ray Dose Levels

It should be pointed out that no definition exists for a minimum acceptable dosage of X-rays. All ionizing radiation has some effect on the various organs of the human body; and while the dosages involved are extremely small, a careful analysis of the risk versus benefit must be made before any attempt is made to place the personnel X-ray system into an actual application area.

The second X-ray system which is under development at USAMERDC is a unit intended solely for the examination of hand-carried articles. The electro-optical hardware employed in this unit is the same as that utilized in the personnel system. The package unit is really a spinoff from the personnel system and, as such, is more of a breadboard laboratory device.

In designing the system the prime emphasis was on versatility. The X-ray source is a Sperry self-rectified unit with a variable kilovoltage range of 40 to 160 KVP and has been modified to provide an electronically controlled X-ray pulse duration of 1/60 to 2 seconds. The variations in kilovoltage and exposure time are extremely useful features when one is not positive of the particular class of targets which may be encountered. Lower kilovoltages provide the best contrast in the radiograph when trying to detect explosives in a relatively light container. The higher kilovoltages and longer exposure time are particularly useful when trying to penetrate large, dense packages containing hand weapons.

The transport mechanism for handling the packages incorporates two 45° rotations which can give the operator (in theory) additional information by providing different perspective views of the target. Results of some preliminary testing indicate that the 45° tilt does not, however, supply much additional useful information for the class of targets expected to be encountered. If a weapon was by chance presented with its major plane perpendicular to the fluorescent screen, only a tilt of 10 to 15 degrees was required to make it readily apparent to the operator as a weapon. If the suspected weapon was hidden behind a dense object or lost in clutter, 45° was usually insufficient to remove the confusing background.

A final constraint on the system was that it met the requirements of National Bureau of Standards (NBS) Handbook Number 93 for an exempt protective installation. This requirement of 0.5 mR per hour at 2 inches from the case surface will require some shielding of the entire unit, but will enable the placement of the system in any location with complete safety to individuals located in surrounding areas.

Figure 7a schematically portrays the system. Note that the overall operation is identical to that of the personnel system, with two notable exceptions. The operation is, firstly, under complete operator control; and secondly, additional video storage and display for up to three separate radiographs have been provided. The additional storage feature enables the operator to view three separate package orientations simultaneously. Also, a three gun color monitor has been incorporated into the system for the explicit purpose of determining if radiographs taken at different kilovoltage levels could be superimposed in a single display to provide a maximum amount of information and discrimination for both high and low Z materials.

A pictorial of the package unit is shown in Figure 7b. As can be seen from the drawing, the X-ray source which is positioned near the floor fires vertically through the package handling mechanism and package and is then incident on the fluorescent screen. The screen is excited by the X-rays and emits light. Two plane mirrors transfer the light image on the screen to the electro-optical detector. Instead of the Angénieux 18mm focal length lens, a Canon 50mm, f/0.95 35mm camera lens is employed as the objective for the system. The image intensifier and TV camera are identical to those used in the personnel X-ray.

A relatively small sample of briefcases and purses were selected at random from the personnel within the CM/CI Department at USAMERDC in order to define the practical working problems within the system. Typical results of this survey are presented in Figures 8a through 8h.

A briefcase was deliberately loaded with actual hand weapons (Figure 8a) in an attempt to determine the operator's interpretation capability. As may be seen from the figure, a .25 calibre automatic and a .22 calibre revolver are plainly visible. This particular attache case contained relatively few clutter items; only an 8-foot steel measuring tape (rectangular object on right) and a tire pressure guage (left) were present in the original case. The shaded areas on the interior of the bag are due to books and papers. Figure 8b portrays the identical briefcase without the hand weapons.

When background clutter was more prominent in the display, the ability of the operator to discern potential threats became severely impaired. A briefcase (Figure 8c) which contained various hand tools and drafting implements was radiographed. While the .22 calibre pistol is readily apparent, the .25 automatic is completely lost behind a 200-foot steel tape and several clutter items. This picture illustrates the biggest operational difficulty encountered in any X-ray imaging system, that of operator interpretation in the presence of an extraneous background. A similar radiograph of the same briefcase with no weapons is shown in Figure 8d, and while several articles are readily apparent, it is evident that it would be quite simple to hide small hand weapons in the clutter.

The second major class of hand-carried articles which are expected to be encountered in an inspection scenario would be ladies' purses. Figures 8e and 8f are radiographs of the same purse taken

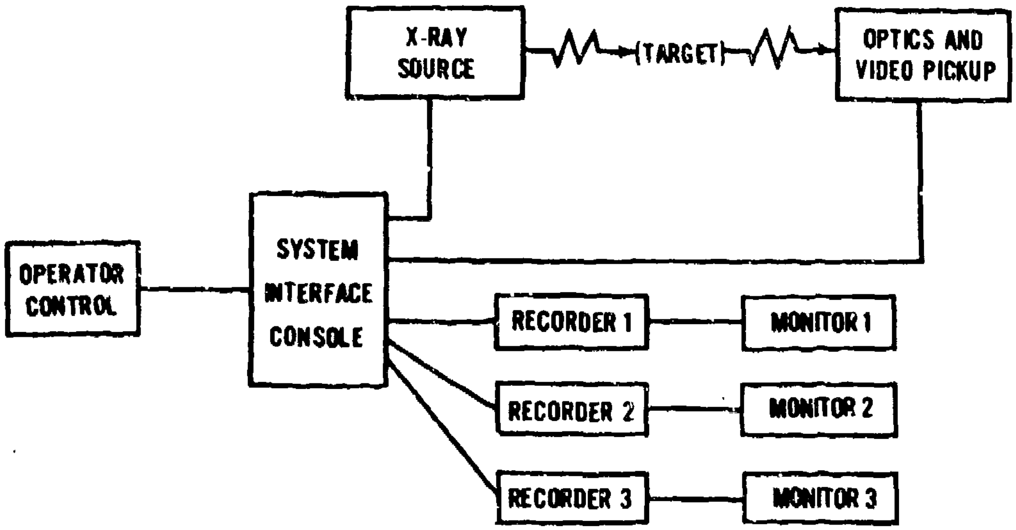


Figure 7a. Package Inspection Block Diagram

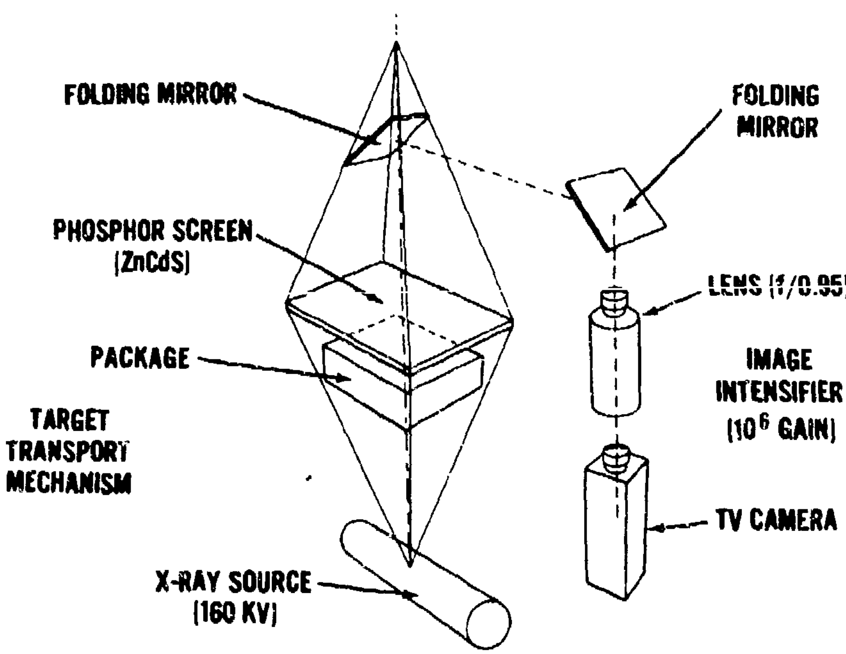


Figure 7b. Package Inspection Unit

with and without actual weapons. A hand grenade and a .25 calibre automatic are contained in one photograph. While it was found that relatively little operator experience was needed to recognize the obvious clutter items (change purses, keys, lipstick), the variety of materials which could be contained in a woman's purse poses a formidable interpretation problem. Also, the oval shape of a grenade could easily be misinterpreted for a compact.

The final two figures are presented to show the effect of a 90° perspective change. Again, a woman's purse and a .25 automatic was used as the target. The first view (Figure 8g) is of the purse with the weapon only tilted about 15° with respect to the fluorescent screen. Even with only this small angle the .25 calibre automatic is clearly seen. A full 90° tilt was made of the purse and is shown in Figure 8h. While the weapon is somewhat more prominent and easier to discern, not much improvement in the interpretation of the display could be expected between the two views.

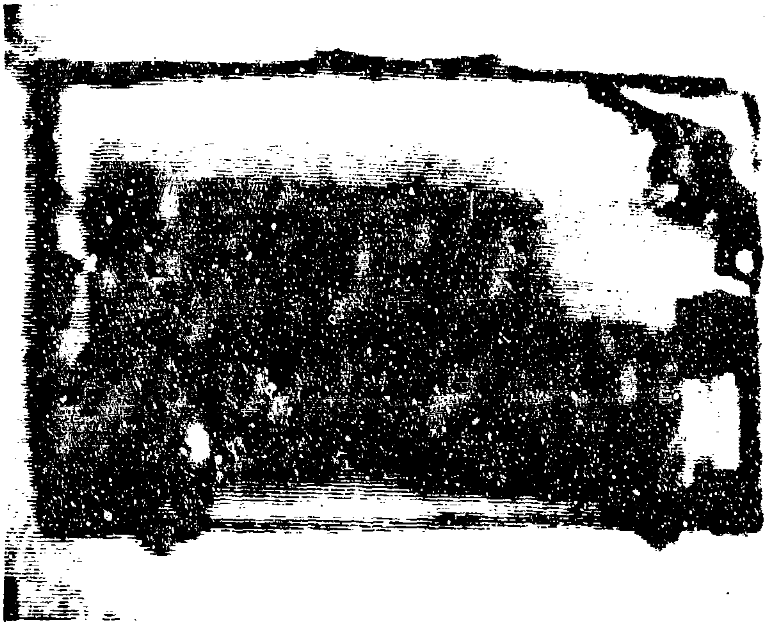


Figure 8a. View of Briefcase With Weapons

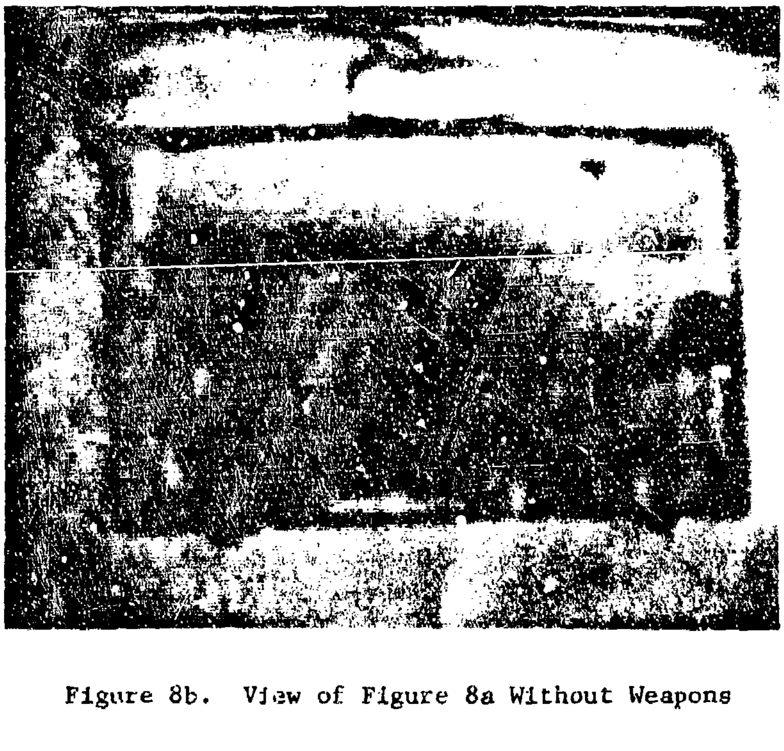


Figure 8b. View of Figure 8a Without Weapons

Figure 8c. Briefcase With Weapons and Increased Clutter

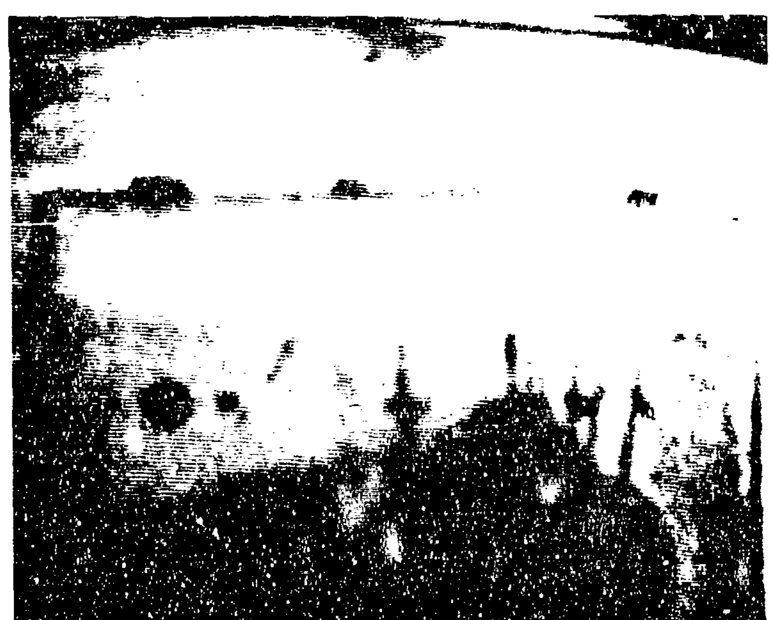


Figure 8d. View of Figure 8c Without Weapons

Figure 8e. Lady's Handpurse With Weapons

Figure 8f. View of Figure 8e Without Weapons

Figure 8g. Lady's Purse With Weapon Tilted at 15°

Figure 8h. Lady's Purse With Weapon Tilted at 90°

IR IMAGING OF CONCEALED WEAPONS

By: Gerald Gallagher, Intrusion Detection Division, CM/CI
Department, USAMERDC

One of the main areas of interest under the Mobility Equipment Research and Development Center (MERDC) Protection of Key Public Figures Program is crowd surveillance. The Crowd Surveillance Program is directed toward the detection of weapons, explosives, and gunflashes in an uncontrolled crowd situation. This situation may range from public rallies and conventions to riot areas. The various scenarios impose certain system requirements which must be met by an imaging system.

The system must operate in real time. Detection in such situations must be instantaneous so that effective actions may be taken. It must be mobile--capable of being moved to any area in which it is required. The equipment must not present any hazard, such as radiation, etc., to the crowd being surveyed; and it must not restrict the normal free flow of a crowd.

It is anticipated that the system would be used in conjunction with security agents intermixed throughout the crowd. These agents would be in contact with the surveillance system operator, so as to direct surveillance on suspect persons and to take the necessary action if a weapon were detected.

Various technologies have been or are currently being investigated for the detection of concealed weapons. Infrared techniques are among those being considered. Infrared is that portion of the electromagnetic spectrum which lies between visible light and 1000 microns (See Figure 1). Any object above absolute zero degree temperature radiates some energy in the infrared region.

An infrared imaging technique was evaluated by MERDC under a previous program. The equipment evaluated was a medical type infrared scanner which operates in the 8-14 micron region. The results of the evaluation showed that a 20° C difference between a gun and room temperature was required before a weapon, concealed by a normal suit coat, could be imaged. Even then, folds in the coat tended to obscure the image. In a concurrent effort, measurement of the transmission of various materials was made to determine the optimum wavelength of operations of an imaging system. The study indicated that the region above 250 microns was favorable. Representative results are shown in Figure 2.

As you can see, the transmission is approaching 50 percent as the wavelength approaches 500 microns. As a result of the transmission measurements, a program was initiated to develop a laboratory, feasibility model, long wavelength infrared scanner. This scanner was developed under a contract with Texas Instruments, Incorporated. The system is completely passive, requiring no illumination of the target. The system is being designed to be used in the crowd surveillance scenario; however, it may find additional applications in a controlled access situation.

Characteristics of the present system are shown in Figure 3. The approximate size and power consumption are shown. The field of view, 100 x 300 milliradians is equivalent to 1 x 3 feet at 10 feet. The resolution is 2 milliradians, which is equivalent to 1/4 inch at 10 feet. Two scan times were incorporated in the system, 2.54 seconds and 25.4 seconds. The scan times represent the time it takes to take one complete picture. Two detectors were evaluated in the program, Gallium Arsenide, which operates at 300 microns, and Indium Antimonide, which operates at 700 microns. Figure 4 illustrates the operation of the scanner.

Energy from an individual resolution element in the object-plane is relayed by the vertical scan mirror and the horizontal scan mirror to the primary collecting mirror. This mirror focuses the energy through a hole in the horizontal scan mirror into the detector which is located in the image plane. By rotating the vertical scan mirror and causing the horizontal scan mirror to oscillate, the individual resolution element "seen" by the detector is varied. Approximately 2.5 seconds are required to complete a total scan. Figure 5 shows the scanner as it presently exists.

In Figure 5 you will notice the vertical scan mirror, the horizontal scan mirror, the primary focus mirror, and to the right, our Dewar. The Dewar is filled with liquid helium to cool our detector to four degrees above absolute zero. Figure 6 shows the completed scanner, with its cover on. You will notice two things: the rectangular opening, which is the aperature through which the energy enters the scanner; and to the left, the recorder assembly which contains the necessary electronics for processing the signal and the oscilloscope type CRT from which final image is photographed. A simplified system block diagram is shown in Figure 7.

As mentioned, two detectors were evaluated in the scanner, Gallium Arsenide and Indium Antimonide. Initial results have shown very little difference in the image quality between the two detectors. However, the Indium Antimonide should give better results on multiple layers of clothing, since the transmission of cloth is greater at the longer wavelengths. The image quality of the present system is shown in Figures 8 and 9. It is obvious that operator interpretation is required to separate the targets from the clutter items, such as eye-glass cases, tie tacks, eye glasses, etc.

While results to date have been promising, we have a long way to go before we have a "fieldable" system. There are some basic limitations which cannot be overcome.

The system optics must be large to provide the resolution required. The present system has an effective collecting aperature of one foot in diameter, and the best resolution it can provide is 1/4 inch at 10 feet. The resolution limit of such systems is a direct inverse of the collecting diameter.

At this time, it may be interesting to compare the scenario-imposed requirements with the present capability of the system. The present system requires 2.5 seconds to take a single picture. This, of course, could not be tolerated in a final system. This present system is a fixed laboratory type and is hazardless--completely passive. However, since it is a fixed focus system, requiring the subject being examined to be 10 feet from the scanner for 2.5 seconds, it can't be considered non-restrictive.

As a result of achievements to date, a detector improvement program has been initiated. This will include improvements to the basic Indium Antimonide detector and the construction of a multi-element array of the improved detectors, so scan time can be reduced and image quality improved. The particular detectors used in this system have not yet been used in any field hardware. Many other areas for system improvement exist, such as optical redesign for light weight optics, variable focus, etc. However, the system's ultimate performance is dependent on the basic detector. When the improved detector array design is realized, a field system may be designed. It is anticipated that if the current efforts are successful, field hardware may be available in the 1977 to 1978 time frame.

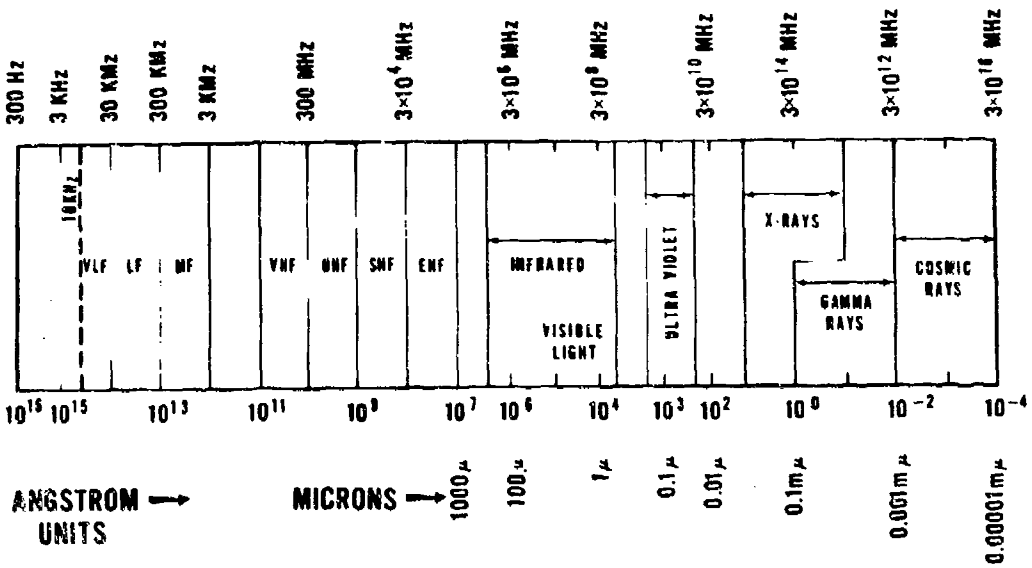


Figure 1. Radiant-Energy Spectrum

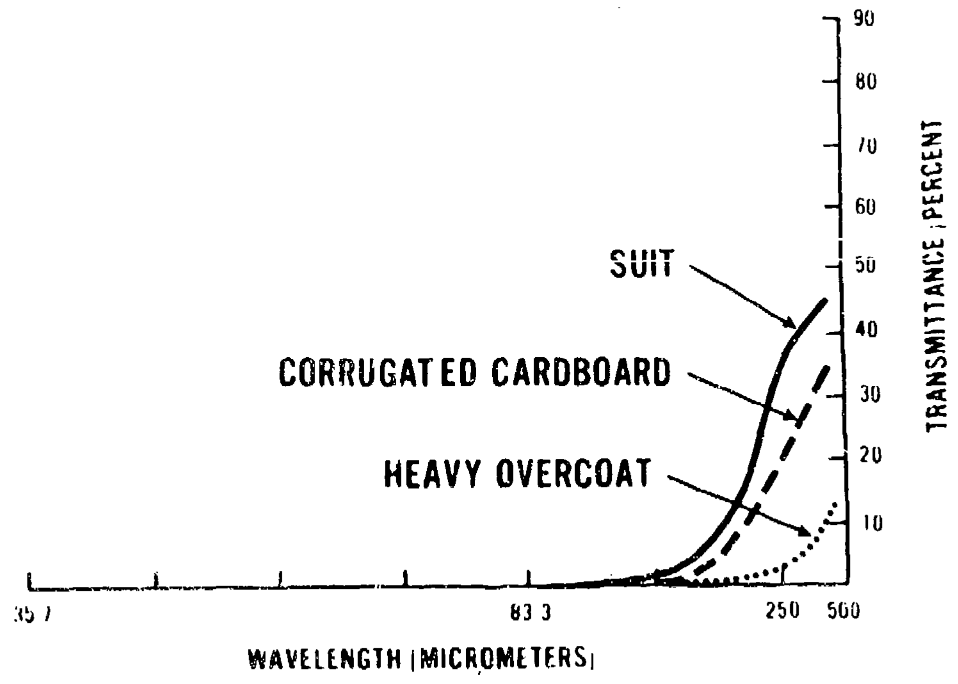


Figure 2. Spectral Transmissivity of Cloth and Cardboard

SIZE	44"·44"·20"
POWER REQMTS	200 WATTS
FIELD OF VIEW	100-300 MILLIRADIANS
RESOLUTION	2 MILLIRADIANS
SCAN TIME	2.54-25.4 SECONDS
DETECTORS	GALLIUM ARSENIDE (GaAs) INDIUM ANTIMONIDE (InSb)

Figure 3. Scanner Characteristic

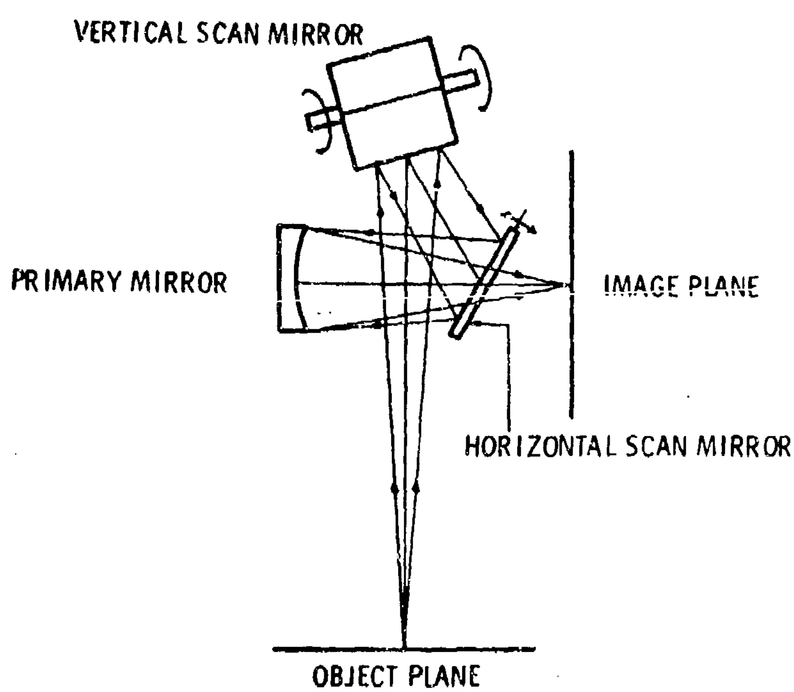


Figure 4. Scanner Operation--Optical Schematic

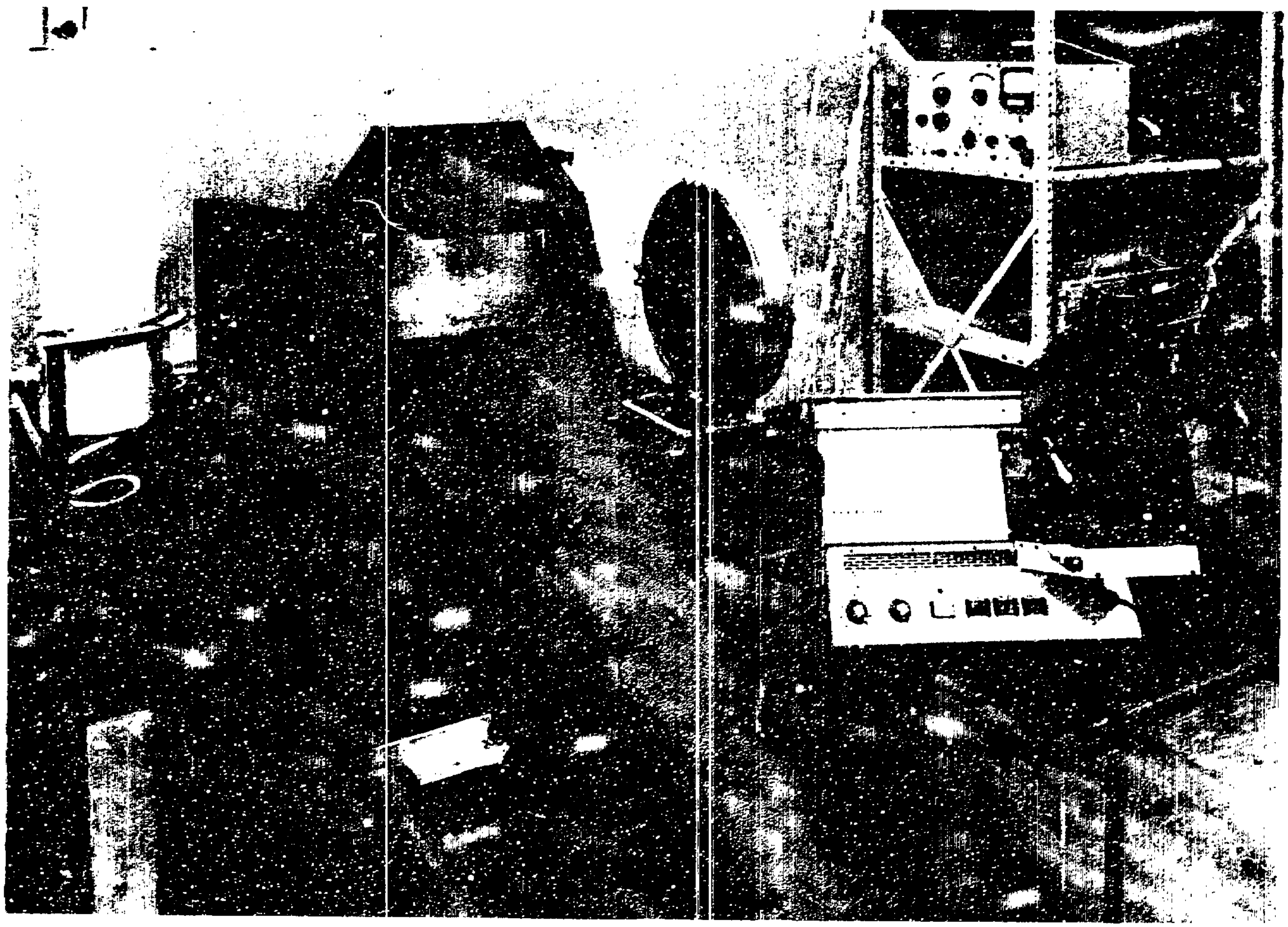


Figure 5. Scanner Arrangement and Components

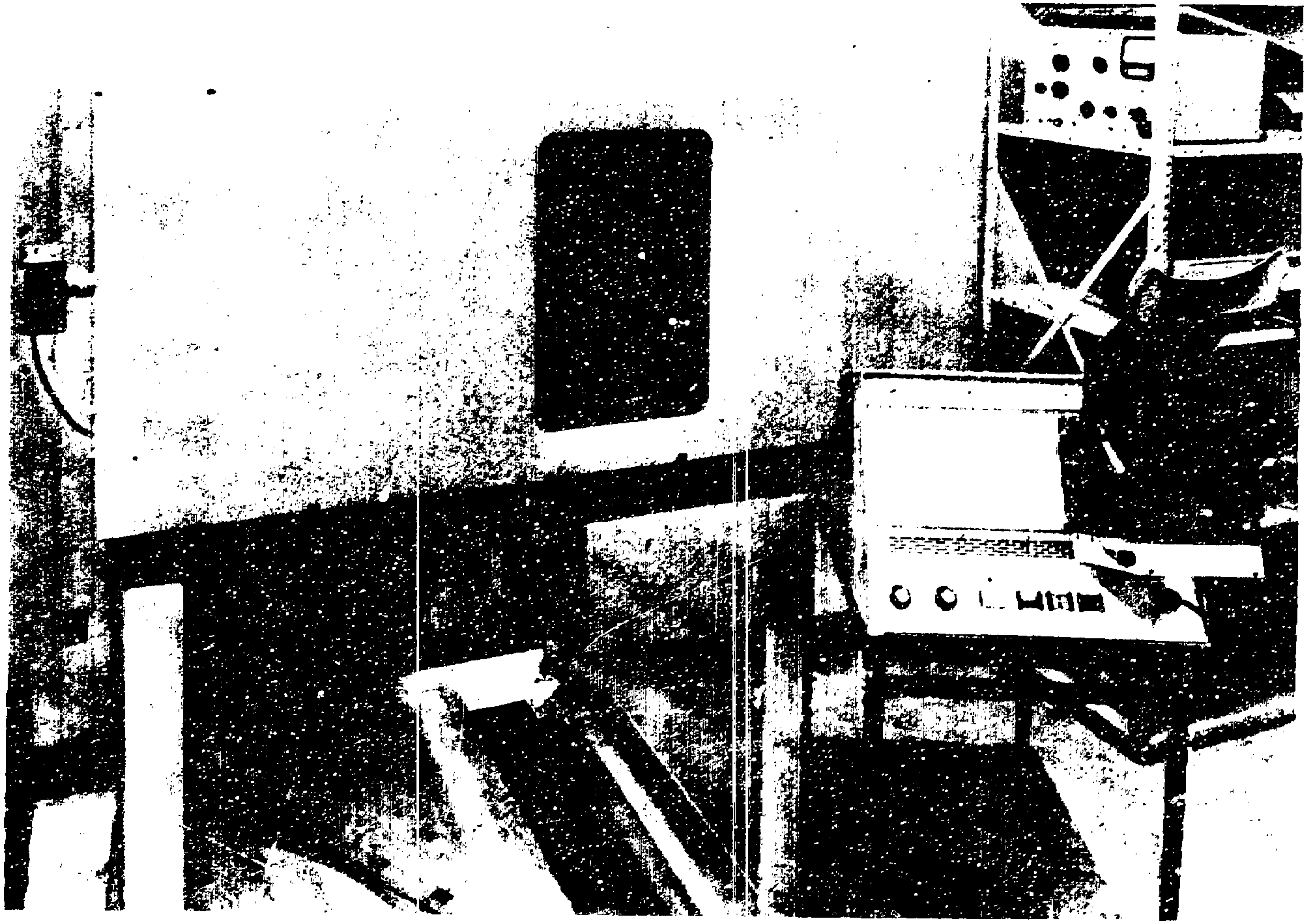


Figure 6. Scanner With Cover

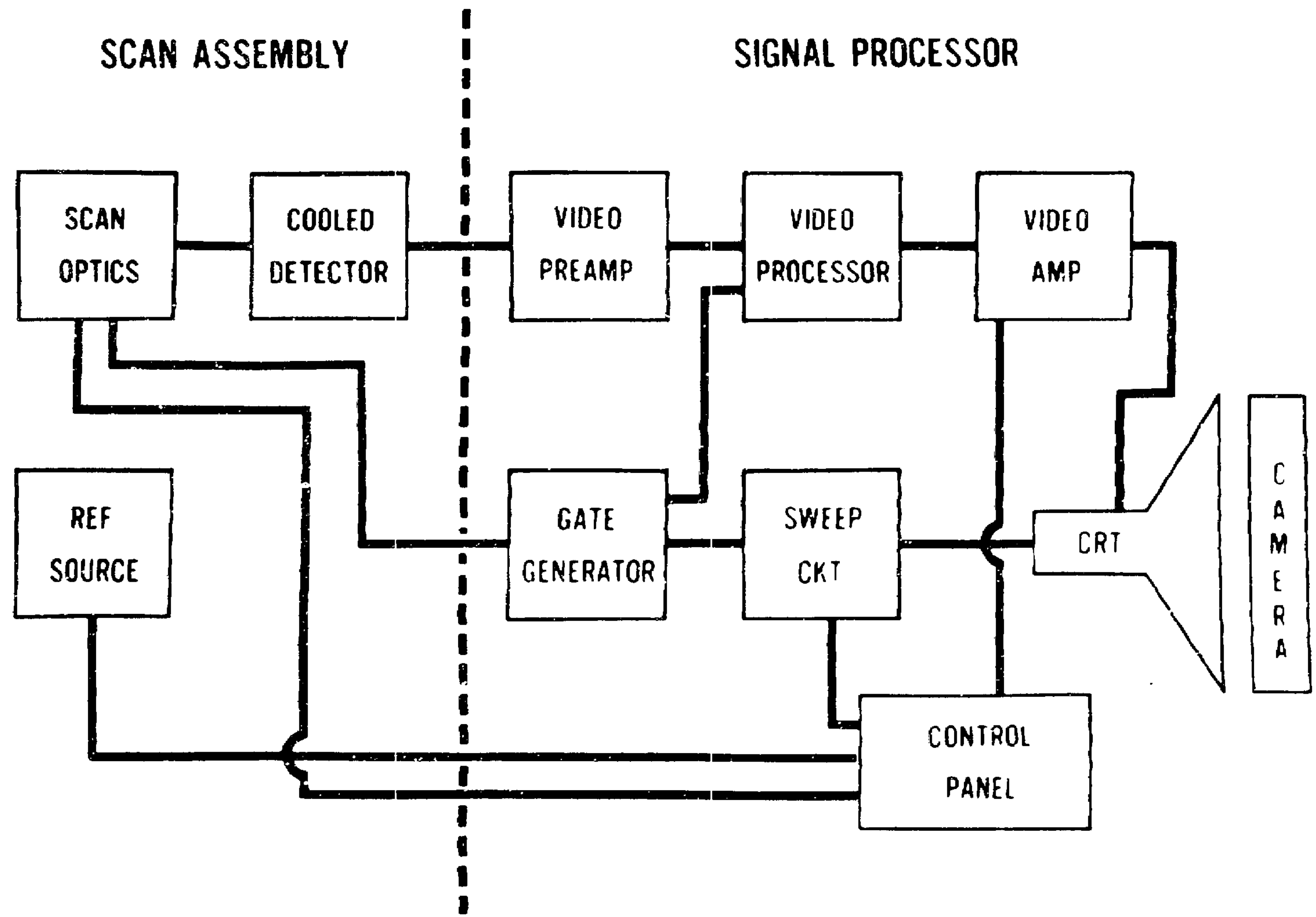


Figure 7. IR Imaging System

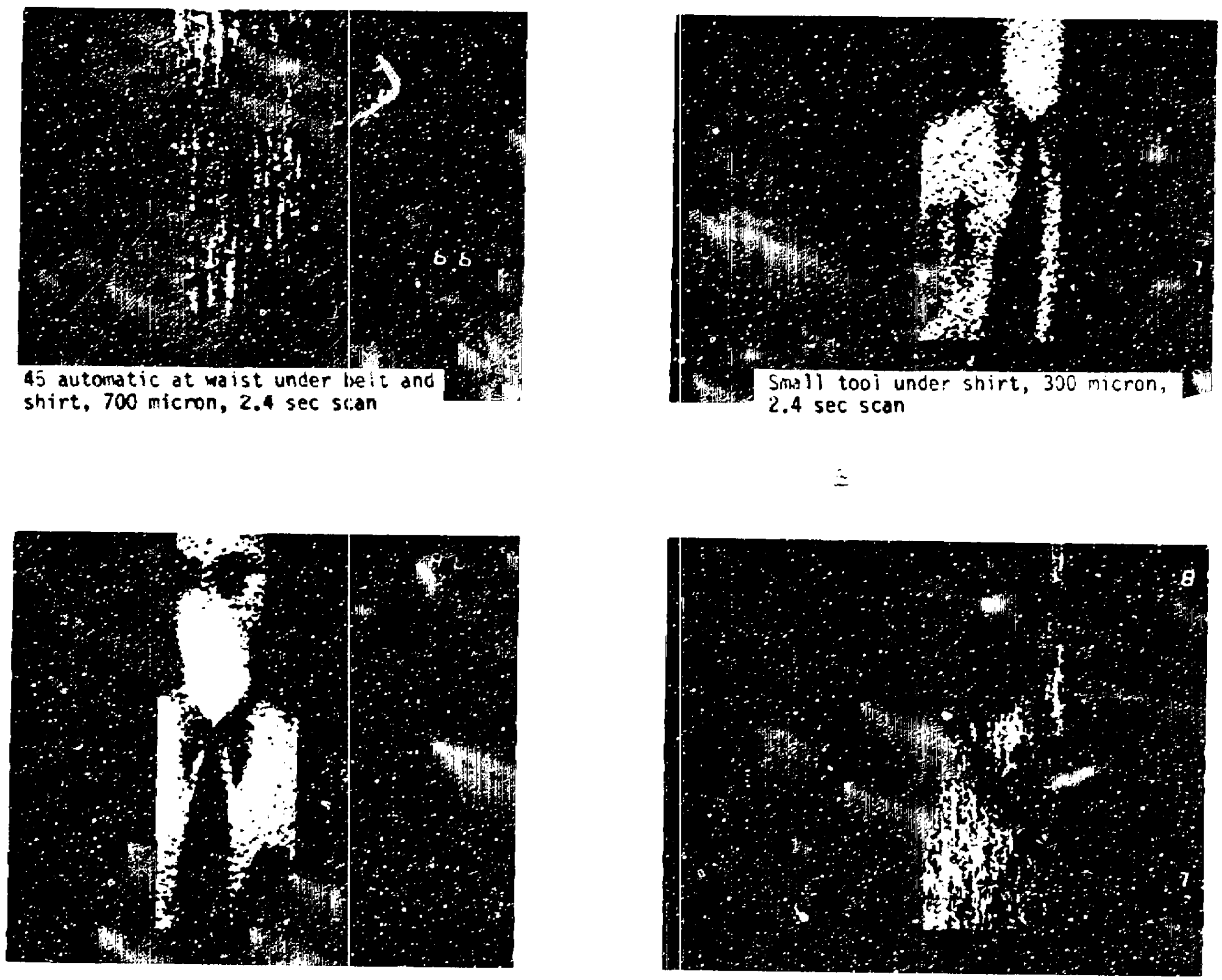
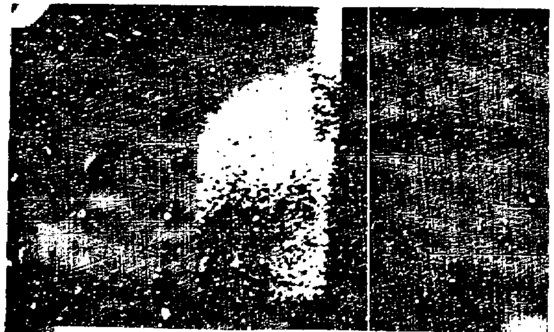
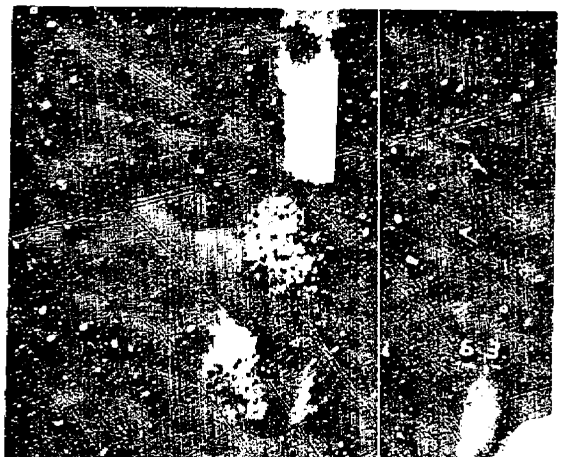


Figure 8. Sample Image Quality Views Taken by Scanner

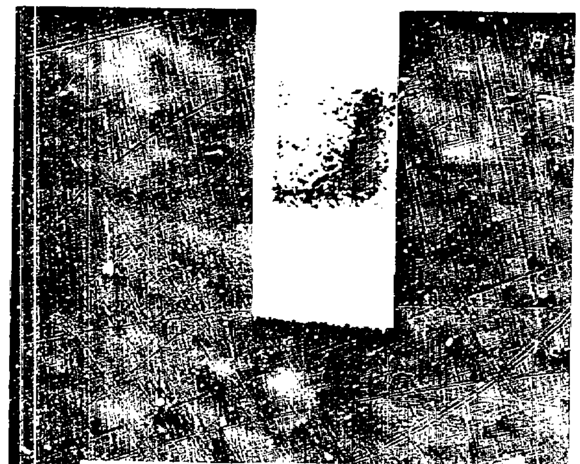


45 automatic under shirt and T-shirt, 300 micron, 2.4 sec scan

45 automatic between shirt and T-shirt, 300 micron, 2.4 sec scan



Back of suit coat (single layer + lining)
45 automatic-300 micron, 2.4 sec scan



45 auto. in corrugated cardboard box, heated background, 300 micron, 2.4 sec scan

Figure 9. Scanner Sample Image Set

MILLIMETER WAVE IMAGING AND APPLICATIONS

By: Albert J. Kerecman, Electronics Technology and Devices Laboratory, U.S. Army Electronics Command, Fort Monmouth, New Jersey

Various techniques operating over the entire electromagnetic spectrum are employed to detect concealed objects. After looking at the various tradeoffs, such as safety, penetration, resolution, detection, and transmission, we have chosen the millimeter wave region as our prime area of investigation into the detection of concealed objects. A growing vision of an imaging system capable of ranging and resolving targets or concealed objects under all-weather conditions is developing due to recent component advances, such as the Schottky and Impatt diodes, and to the maturing of integrated electronics.

Various configurations of an imaging system have been explored at ECOM. Reflection and transmission modes (single and multiple collector), along with single and multiple lens configurations, have been employed.[1, 2, 3] Figure 1 shows a typical example of our early designs. This active device is a transmission mode, single collector, darkspot scanned system. Here, a klystron is used to illuminate the target area. The target returns are imaged by a lens onto a germanium panel which reflects the millimeter wave radiation while illuminated by the projector, and transmits the radiation where the shadow of the dark spot impinges.[4]

This type of device, employing point contact diodes operating in a video mode imaged multiple target, returns from metallic disks 3 cm in diameter as shown in Figures 2a. and 2b. The disks were covered with cardboard and plywood, with very little attenuation observed in the return signals as can be seen in Figures 3a., 3b., and 4a., 4b., respectively. Similar results have been obtained with cloth concealment at 3.2 mm wave length. A systematic study of penetration of various substances has not as yet been carried out; however, weather and resolution problems have been analyzed by Hofer, et al.[5]

At this point, a new approach was taken to reduce the size, weight, and power consumption as well as the cost of the system. The new design concept calls for: eliminating the flying dark spot scanner and replacing it with a P-I-N diode array called an image formation and scanning unit; replacing the video point contact diode with a Schottky barrier diode operating in a heterodyned mode; employing a phase locking technique for better signal to noise and stability performance; and, finally, replacing the klystrons with Impatt diodes. Figure 5 shows a block diagram of the new design with the exception of the employment of the Impatt diodes, which should be possible to incorporate in FY-73. Some of the new circuitry developed in the integrated electronics area can be seen in Figures 6 and 7.

Solid state devices are used throughout, and significant advances in power consumption, size, and weight have been made. In Figure 8 the image formation and scanning unit is displayed with the fixtures used to fabricate the array.

To date, the changes in the system have not only resulted in the reductions mentioned, but real-time imaging at 30 frames per second is now possible. Collector insertion losses have been reduced significantly, mainly due to the P-I-N diode array coupled with its drive circuitry. The new configuration also lends itself easily to frequency changes. The image conversion and scanning unit, while maximized at half wavelength intervals, can be employed throughout the millimeter wave region, having already been tested at 94 and 140 GHz or 3.2 and 2.1 millimeter wavelengths, respectively. In fact, much of the submillimeter wave and far infrared regions should also fall within the operating range of the device. With modifications, the diodes should cover the entire infrared region. Therefore, a real-time imaging capability employing heterodyne detection can exist throughout the infrared-millimeter wave region.

The applications of the above system exist where concealed objects, such as guns, are to be detected over short ranges, whether on a person or in luggage. Also, detection of targets under adverse weather conditions, such as fog or rain, over short ranges is also feasible. Alternative approaches are also being considered, where development of low-cost phase shifters will some day allow phased array techniques to be employed in order to extend the range from 20 to 300 meters to a few kilometers.

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2. Jacobs, H., Schumacher, J. D., and Register, D., "A Bulk Semiconductor Imaging Device for Millimeter and Submillimeter Radiation," IEEE Trans. Elec. Dev., Vol. ED-16, No. 5, pp 419-424, May 1969.

3. Schumacher, J. D., Hofer, R. C., and Jacobs, H., "Performance of a Single-Collector Millimeter Wave Imaging Device," Proc. IEEE, Vol. 58, No. 9, pp 1390-91, Sept. 1970.

4. Jacobs, H., Morris, G., and Hofer, R. C., "Interferrometric Effect with Semiconductors in the Millimeter-Wave Region," Jour. Opt. Soc., Vol. 57, No. 8, pp 993-999, August 1967.

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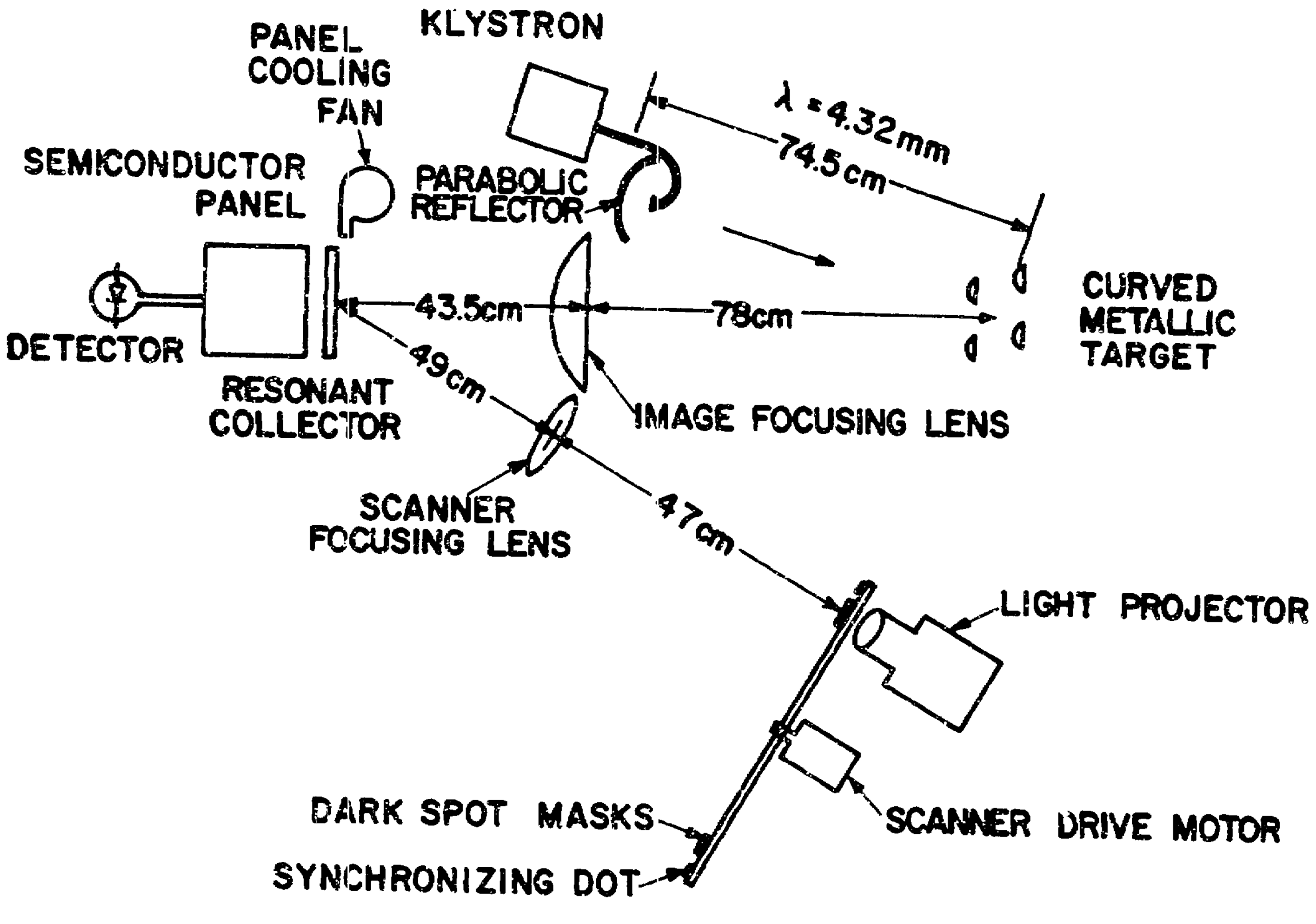


Figure 1. Millimeter Wave Imaging: Transmission System With Reflecting Targets

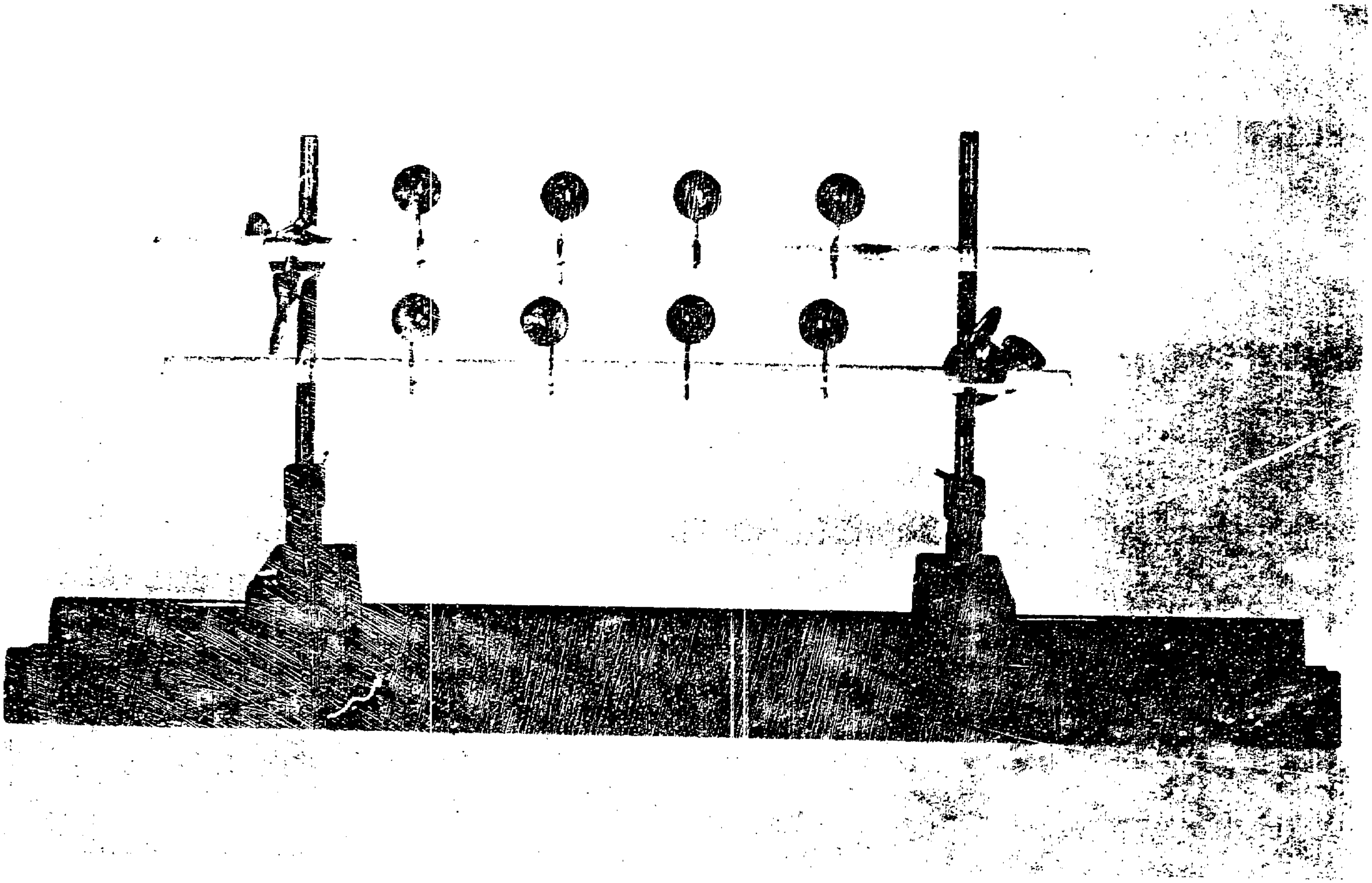


Figure 2a. Reflecting Targets, 3 Centimeters in Diameter

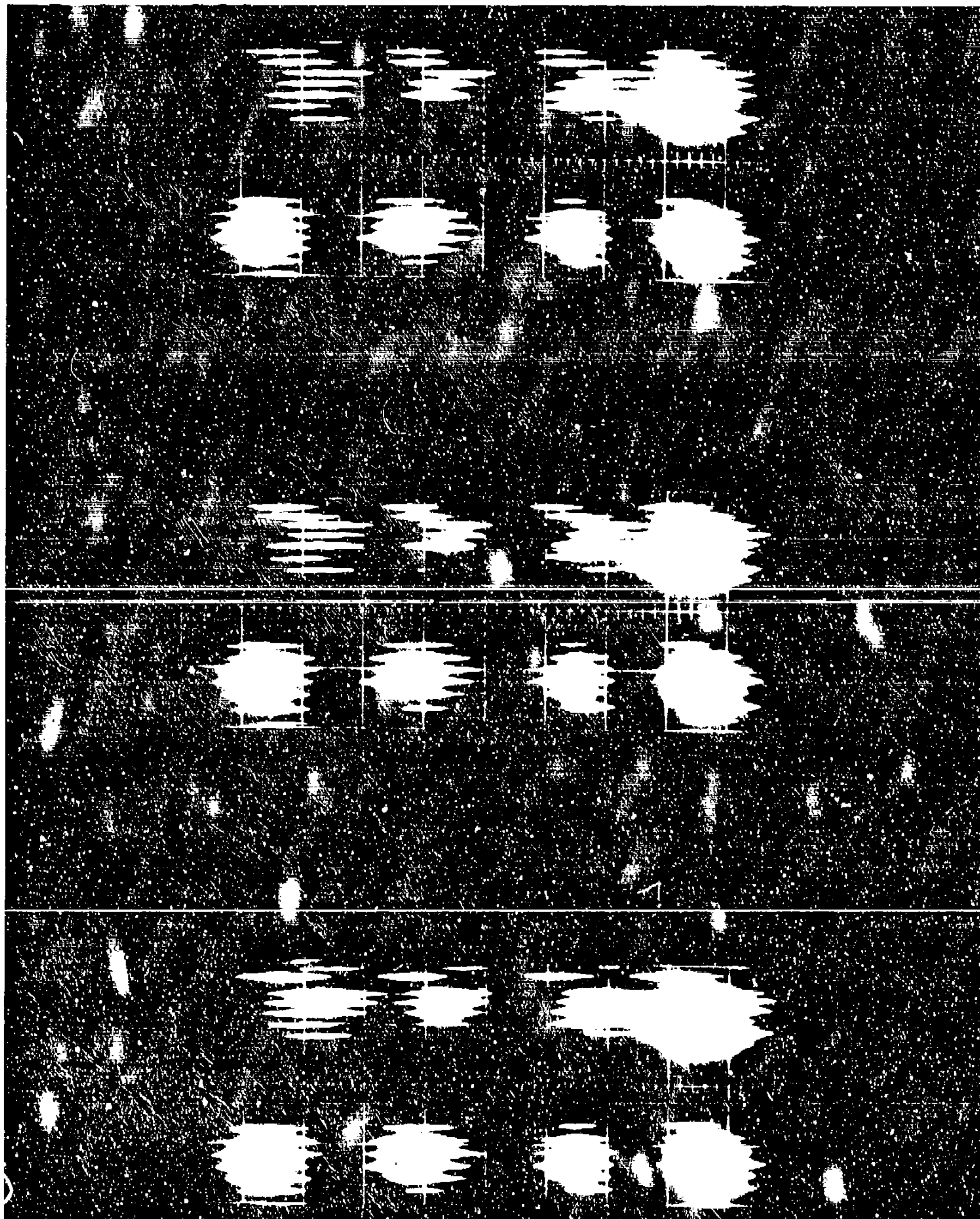


Figure 2b. Millimeter Wave Returns of the 3cm Targets

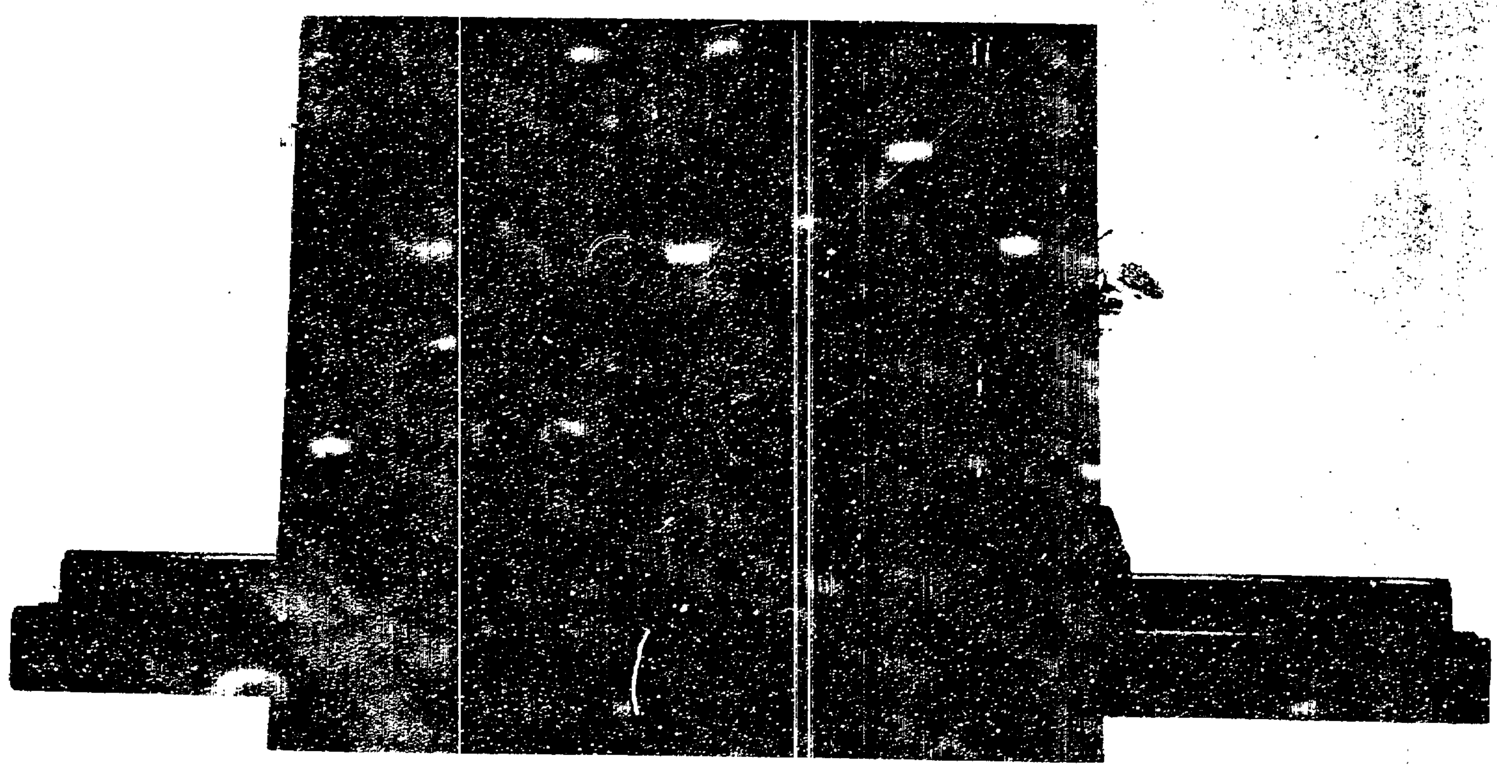


Figure 3a. Targets of Figure 2a. Covered With Cardboard

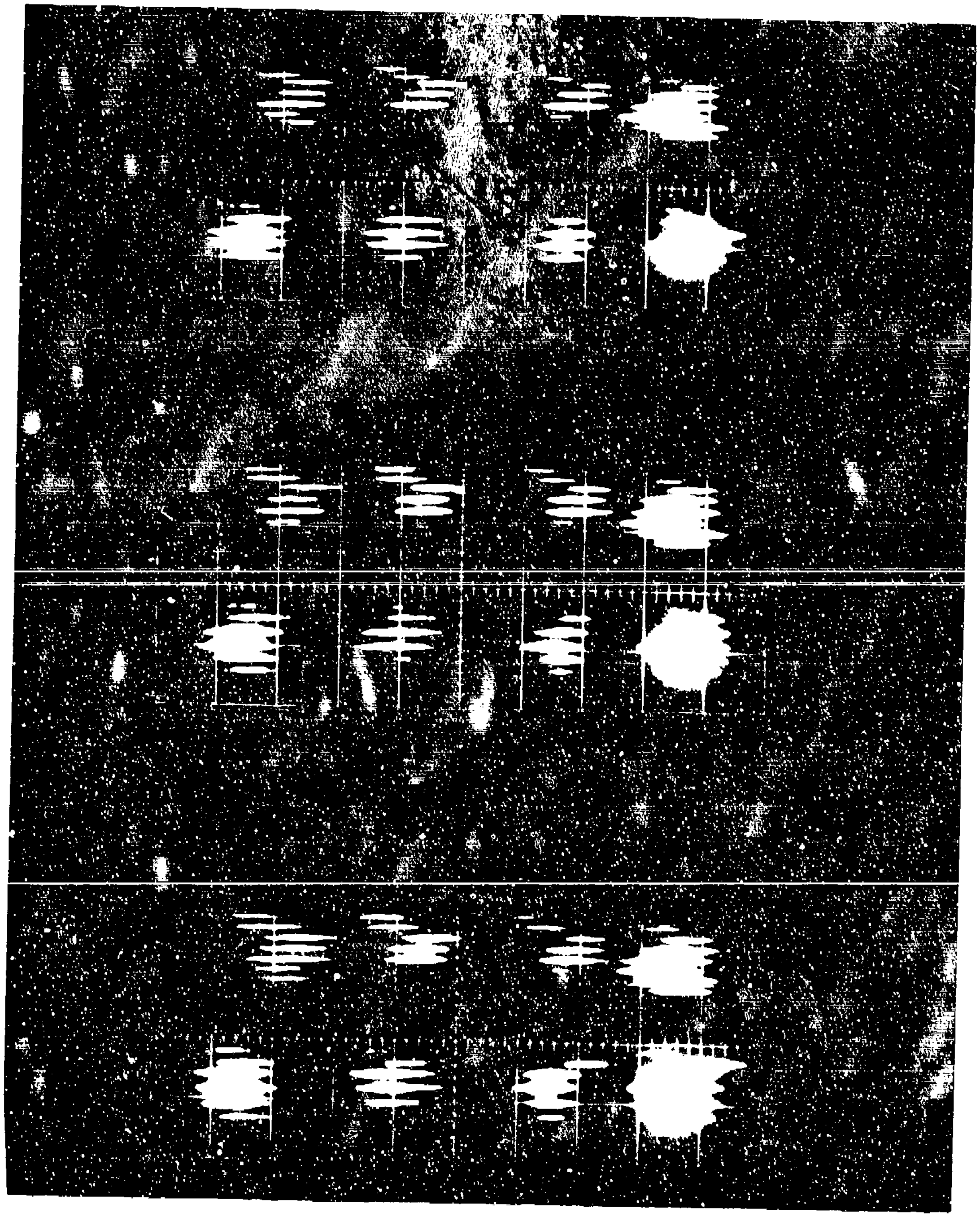


Figure 3b. Millimeter Wave Returns of Concealed Targets

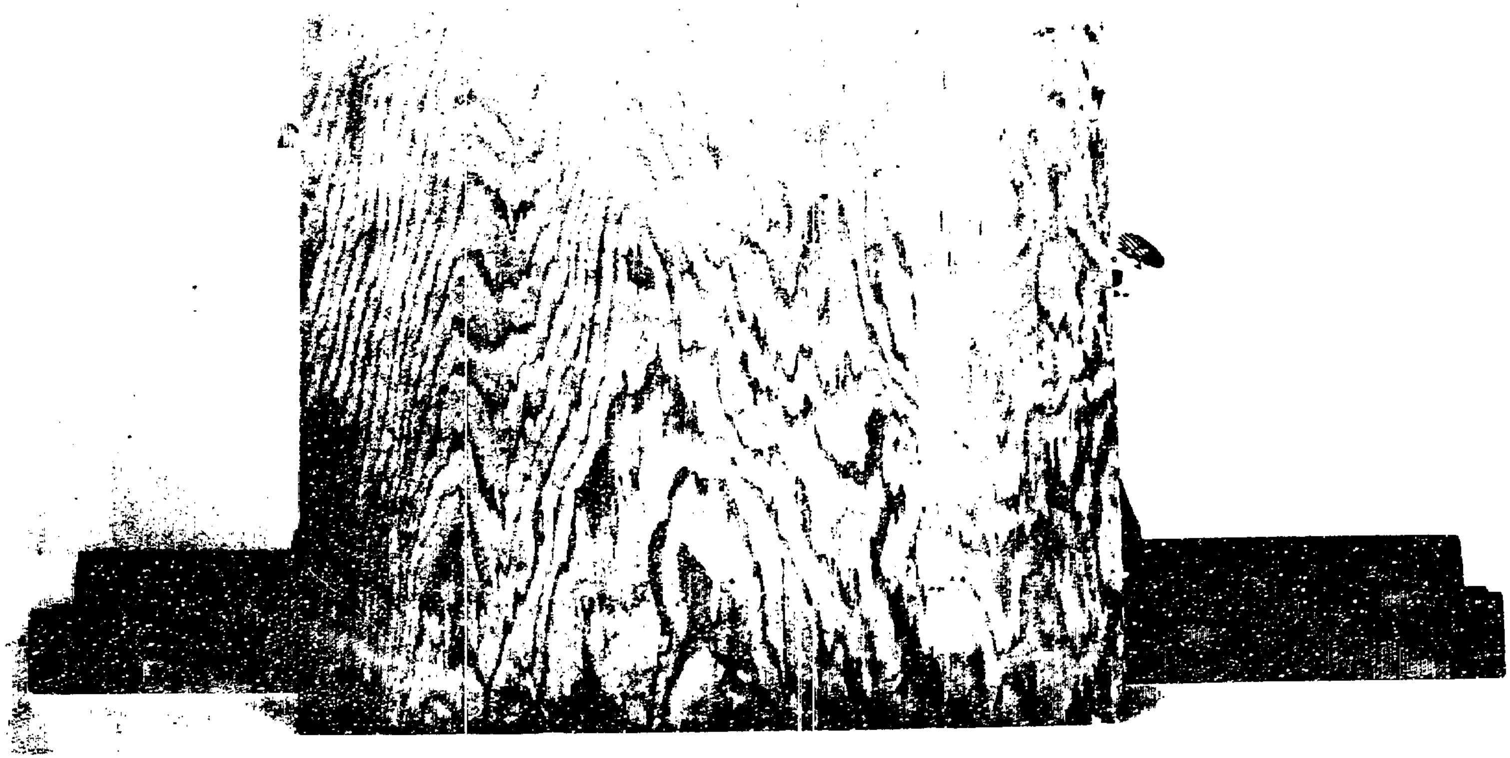


Figure 4a. Targets of Figure 2a. Covered by Plywood

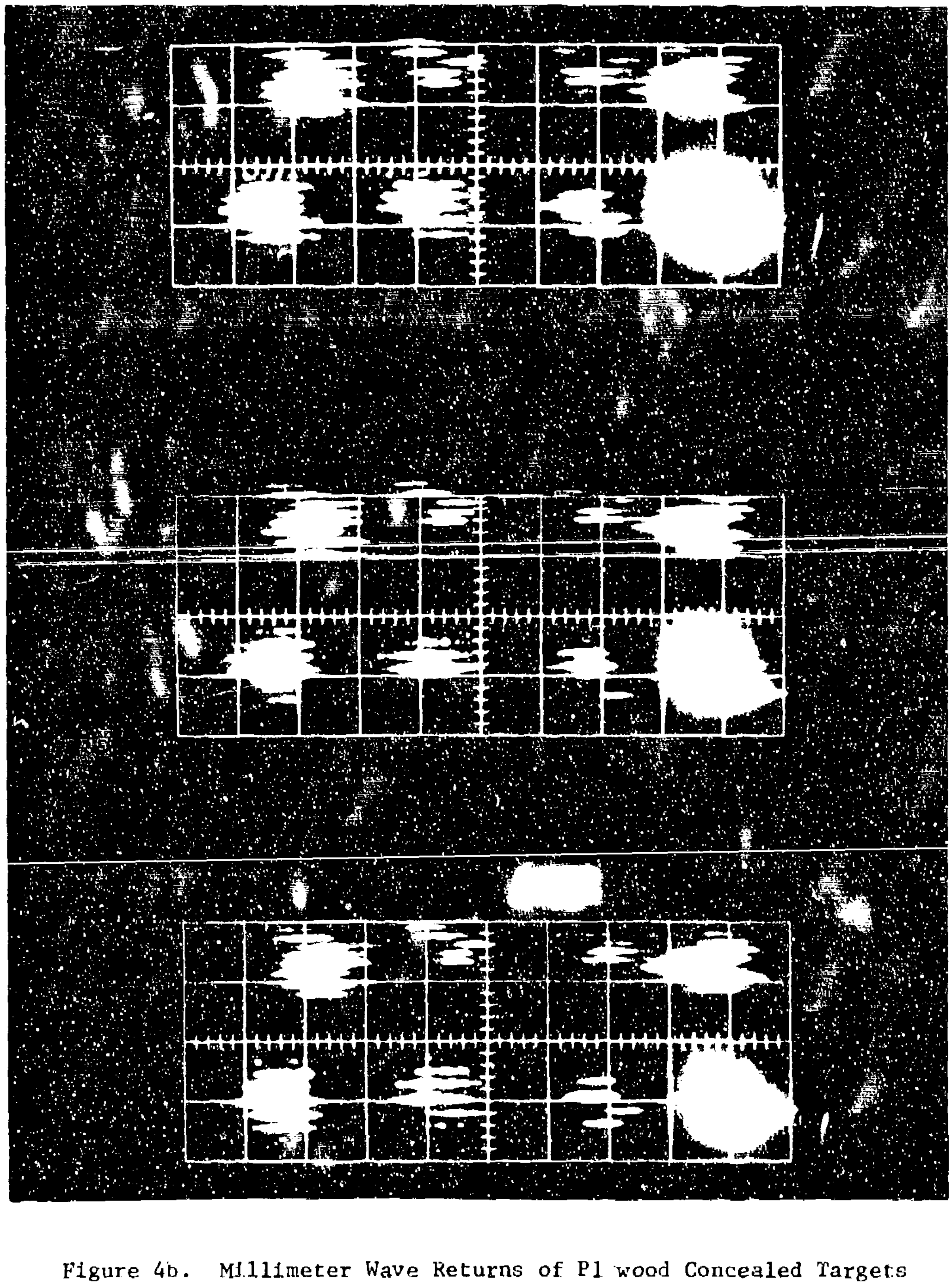
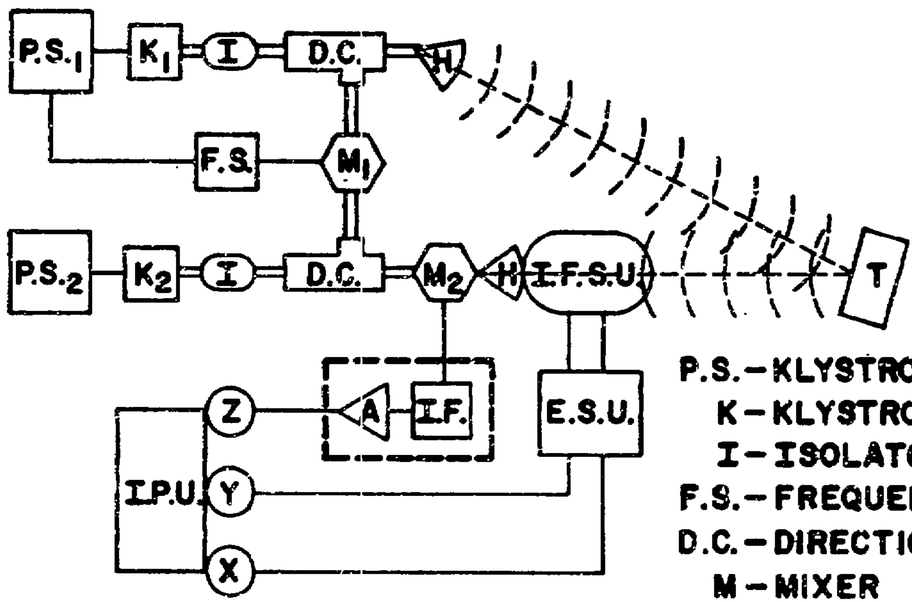


Figure 4b. Millimeter Wave Returns of Plywood Concealed Targets



P.S.—KLYSTRON POWER SUPPLY
K—KLYSTRON
I—ISOLATOR
F.S.—FREQUENCY STABILIZER
D.C.—DIRECTIONAL COUPLER
M—MIXER
H—HORN
T—TARGET
I.F.S.U.—IMAGE FORMATION & SCANNING UNIT
E.S.U.—ELECTRONIC SCAN UNIT
I.F.—I.F. PREAMPLIFIER - AMPLIFIER
A—DETECTOR & AUDIO AMPLIFIER
I.P.U.—IMAGE PRESENTATION UNIT

Figure 5. Block Diagram of Solid State Electronically Scanned Imaging System

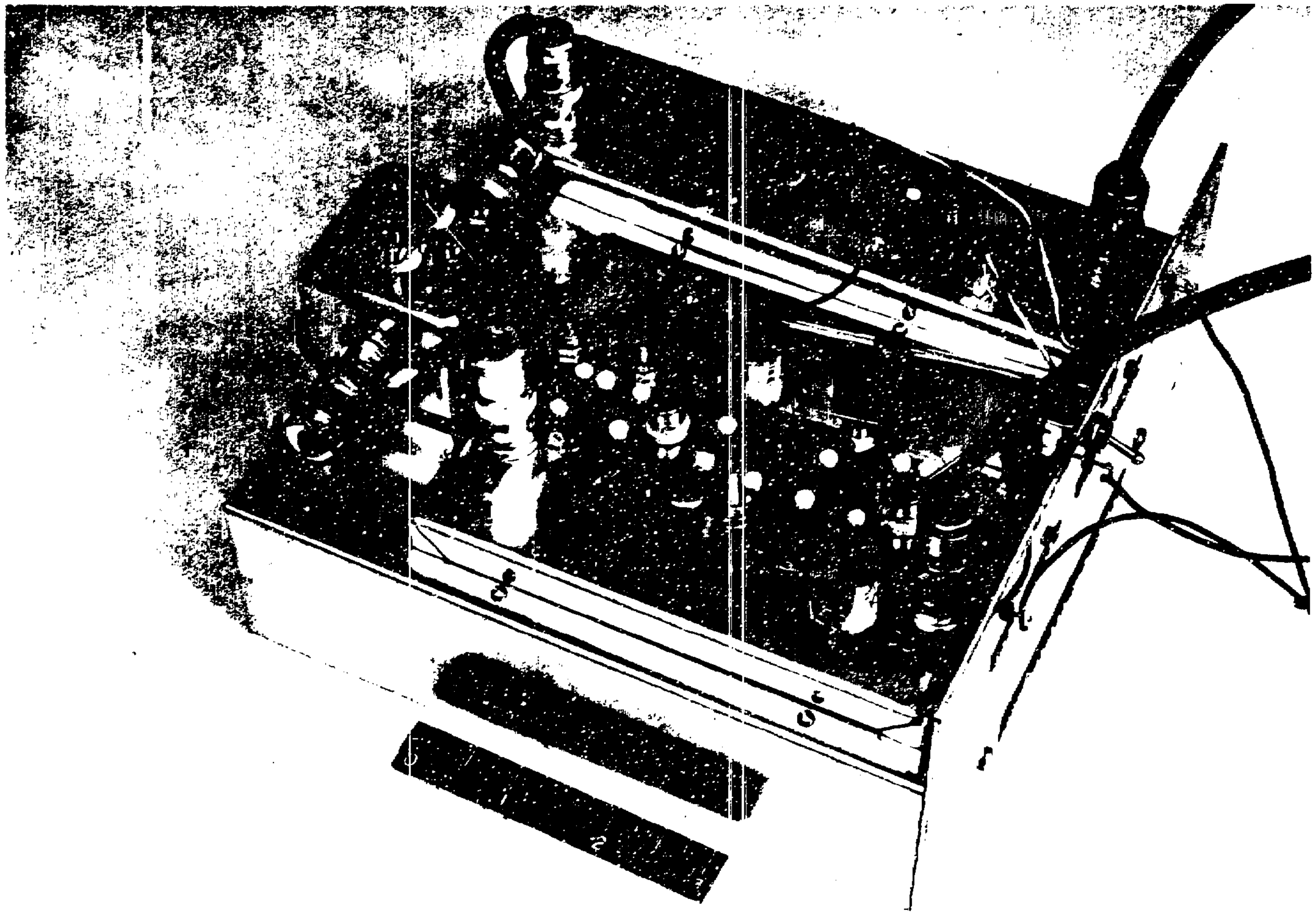


Figure 6. Solid State I.F. and L.F. Amplifier Employing Crystal Filters

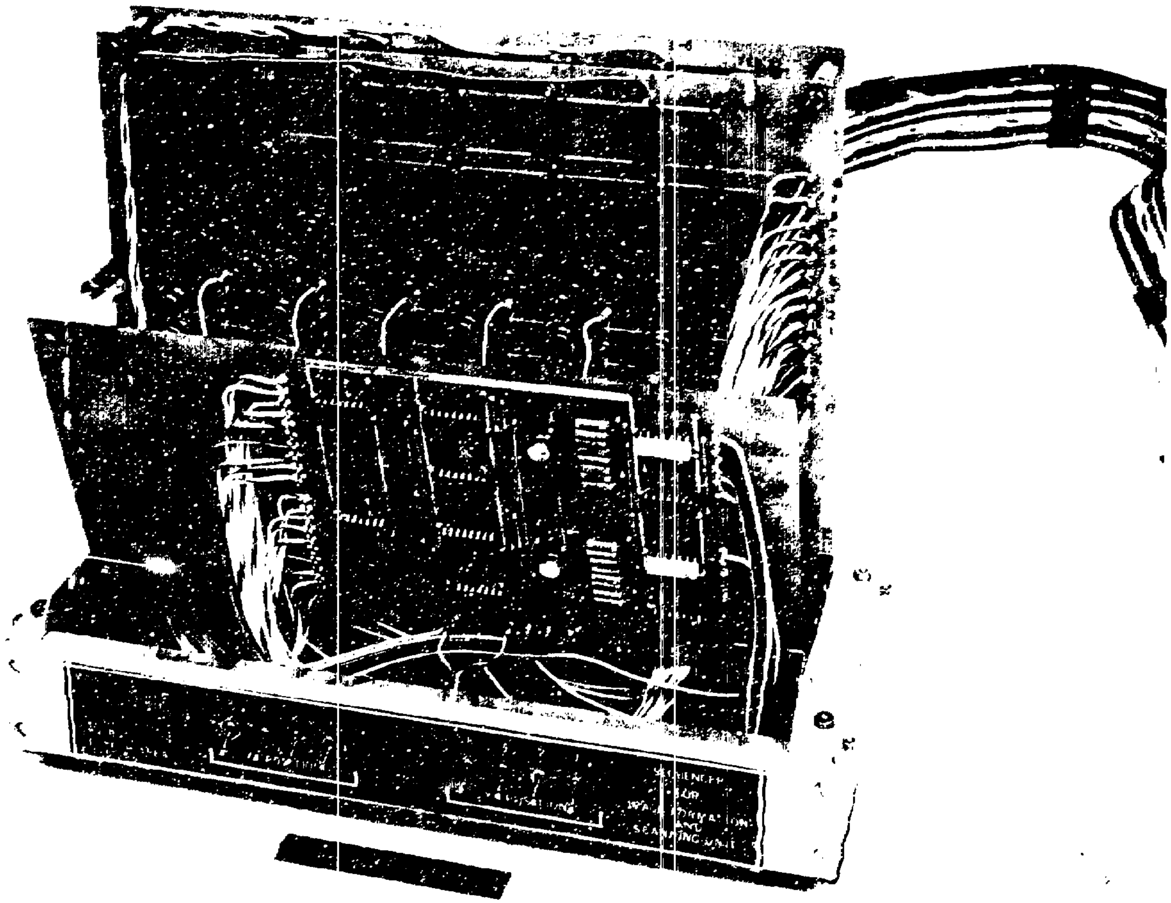


Figure 7. Sequencer for the Image Formation and Scanning Unit

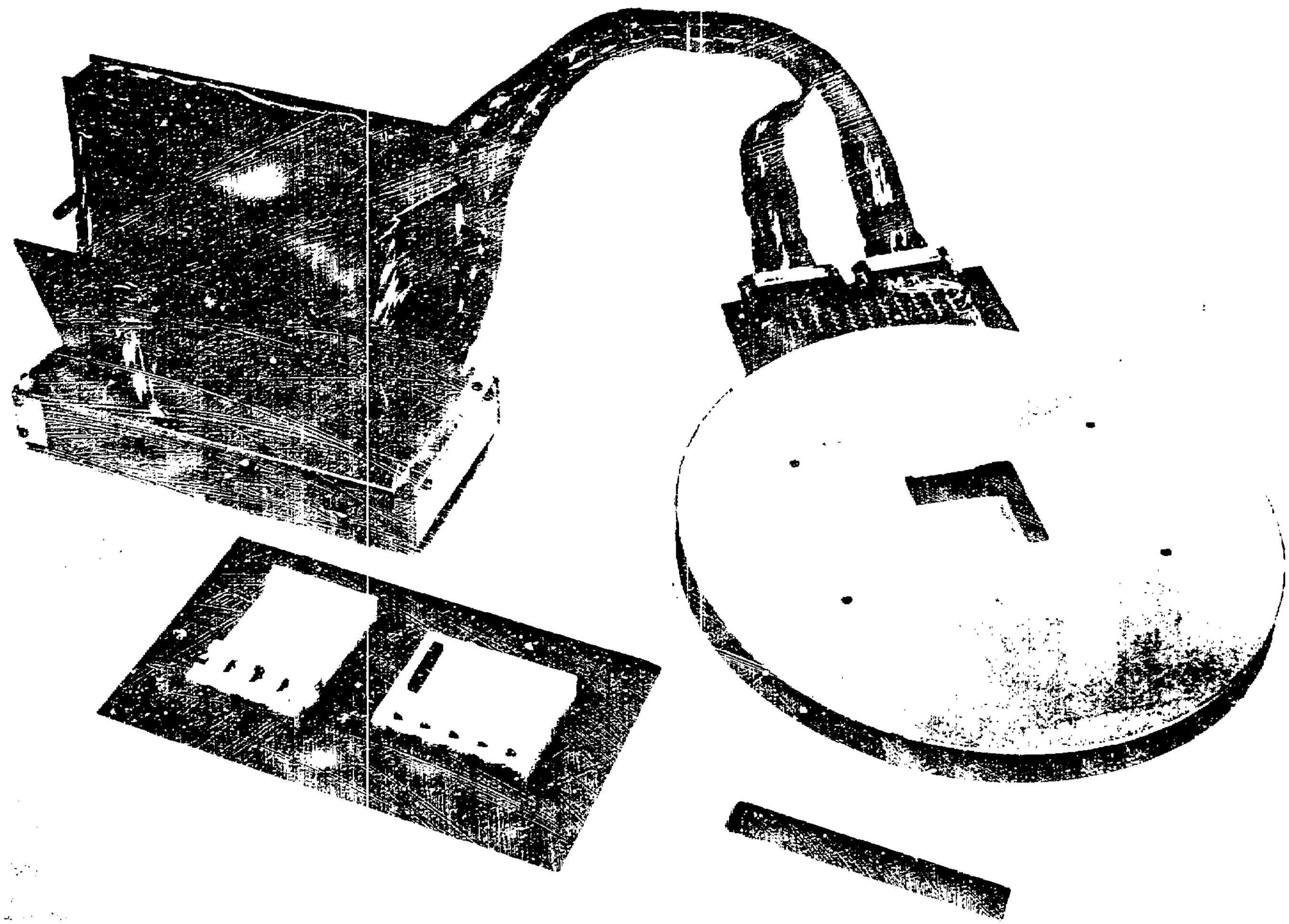
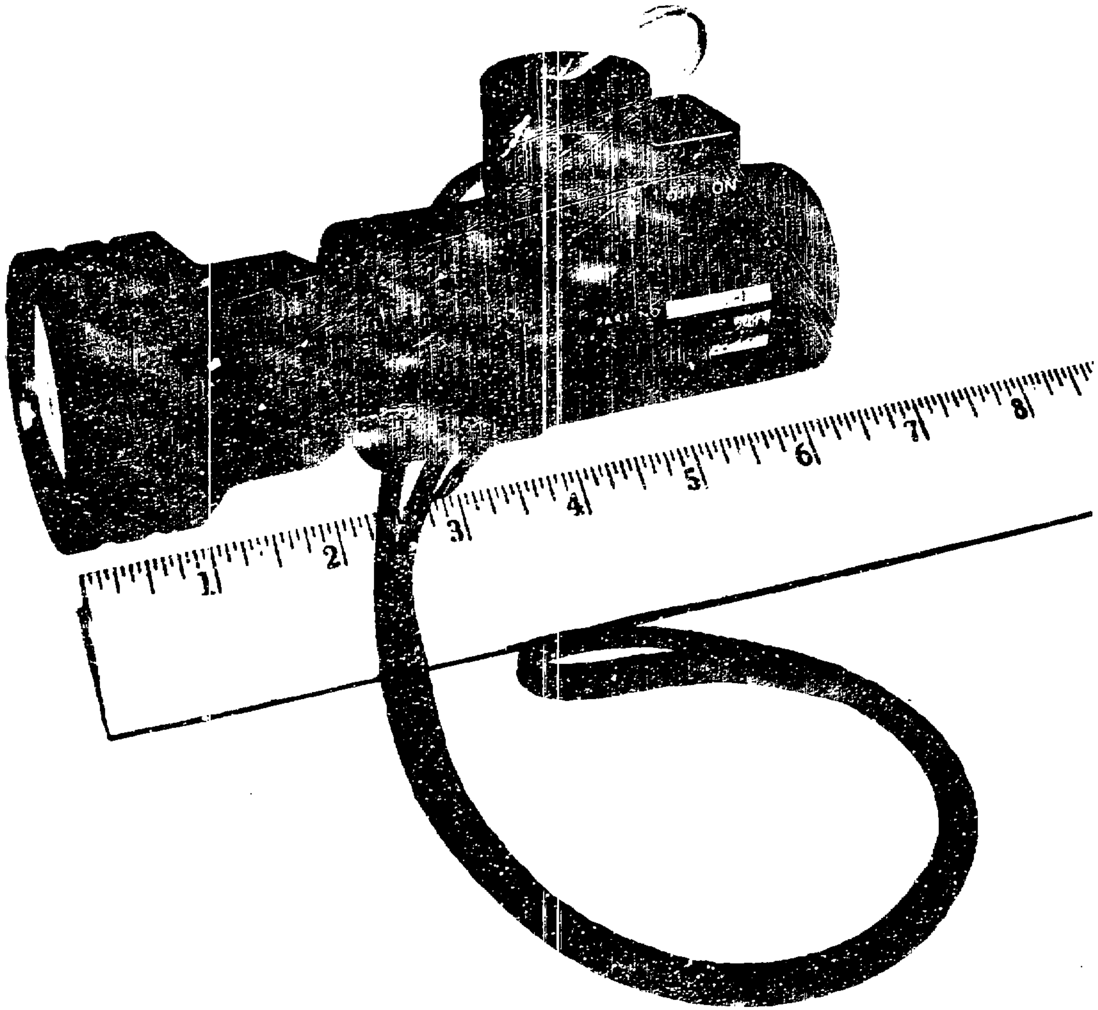


Figure 8. Composite of the Image Formation and Scanning Unit, Showing the Sequencer, P-I-N Diode Addressing Card, Leakage Baffle, and Fixtures Employed in P-I-N Diode Fabrication



Frontispiece. Night Vision Pocketscope

NIGHT VISION POCKETSCOPE

By: David K. Anderson, Night Vision Laboratory, USAECOM

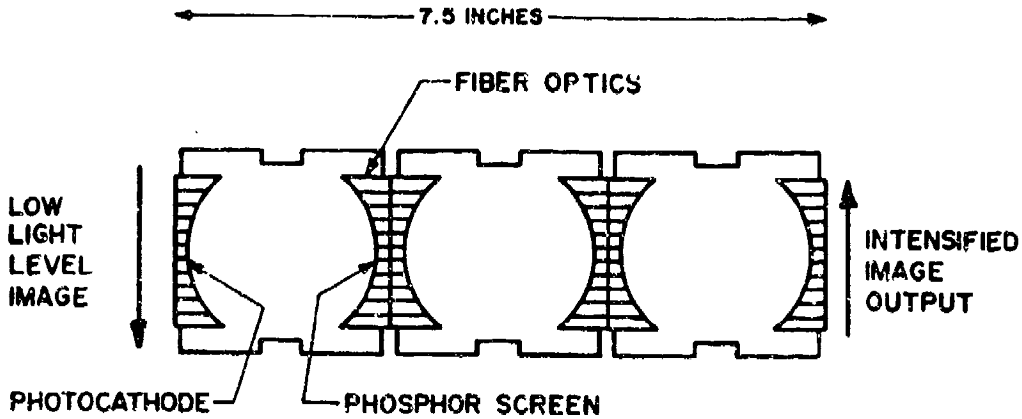
Abstract

Recent advances in electro-optics have made possible dramatic improvements in night vision aids.

The Night Vision Pocketscope is a handheld, passive image intensifier that utilizes the secondary emitting microchannel technology. This device is described as to the various electro-optical parameters involved in its design and usage. Brief descriptions of the secondary emission technique, photocathode, phosphor, power supply, dynamic tube response, classical optics considerations, range performance, and surveillance role are included.

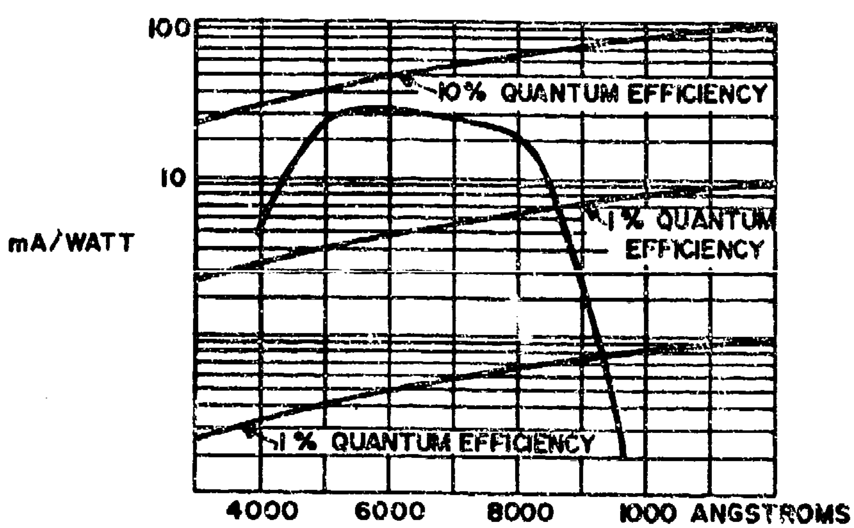
The earliest efforts to remove the cover of darkness consisted of the use of torches, flares, and rockets. During World War I formal research was started to enhance night vision, which, until the 1930s, was confined to searchlight illumination. In the 1930s early television research led to the development of an image tube that could be used to detect targets illuminated by covert infrared radiation. These images were converted into visible displays.

An outgrowth of this infrared research was the exploratory work done on a cascaded image intensifier tube for low light level image intensification which would not require the cumbersome, power consuming infrared light source. This cascaded tube was comprised of three separate stages linked together by fiber optics (Figure 1). The low light level night scene imaged and inverted by an objective lens on the fiber optic input of the cascaded tube was transferred by the individual glass fibers to a photoemissive surface where each portion of the image was converted into a photo-electron(s). The photocathode material utilized was the S-20 photo-emitter (Sb-K-Na-Cs), with sensitivity encompassing the visible spectrum and near infrared (Figure 2). These photo-electrons were then accelerated by a 15KV potential field, whereupon these photo-electrons with increased kinetic energy impinged on a phosphor screen. The brightness of the image on the phosphor screen was approximately 30 to 40 times brighter than the input low light image. This first stage also inverted the image, and the output of the first stage was coupled by fiber optics to the input of a second stage where another image intensification of approximately 30 to 40 times was accomplished. The second stage output was amplified and inverted in like fashion by a third stage so that the resultant output was approximately 20,000 to 70,000 times brighter than the original low light level input. The phosphor screen of the third stage was then viewed with a magnifier eyepiece. The use of three stages was necessary in order



To achieve sufficient gain to see under starlight conditions three stages were cascaded together. The choice of three stages also assured that the world was not upside down when viewed through a night telescope using this tube type

Figure 1. Electron Acceleration Image Intensifier



This semi-transparent photo-emitter converts light protons into photo-electrons so that electronic amplification can be accomplished by acceleration through high potential field

Figure 2. S-20 Photocathode

to get sufficient brightness gain (i.e., output light level divided by input light level) and to correct for the inversion of the scene by the objective lens. The phosphor used was the P-20 (ZnCdS:Ag) because of its superior efficiency (480 lumens/watt) and its green color, which in turn optimized the human eye's greater acuity in the green (Figure 3).

The cascaded tube described above was used in a simple night telescope system where a fast f/number objective lens focussed the dim night scene on the tube. The image was intensified in brightness and viewed with a simple magnifier eyepiece. A family of night telescopes was developed that ran from 6.0 pounds to 45.0 pounds, depending on the passive range performance desired (Figure 4). The advantages that these night telescopes offered were significant, since they required only the dim glow of the stars, moonlight, or faint skyglow to illuminate the nighttime target for truly "passive" observation. The need for infrared illumination for night viewing had been eliminated. The only disadvantages to the three stage devices were their large size and their inability to operate in the presence of bright light sources. The latter problem would become severe, for example, when one attempted to view a low light level scene and car headlights unexpectedly appeared in the field of view. The car headlights were amplified by the same high gain factors as the low light level target, such that they often completely masked the low light level target of interest.

Whereas the wide usage of direct view night vision devices has centered, to date, around the three-stage/cascaded image tube which used electron acceleration as the primary gain mechanism, recent developments in Industry and Government laboratories have led to image intensifier tubes which use the secondary emission technology (Figure 5). The secondary emission channels have been called microchannels and measure approximately 17 microns outside diameter and 12 microns inside diameter. The cascaded tubes used three electrostatically focused stages potted in one 7.5-inch long package, whereas the microchannel tube attains similar gain and resolution in one stage with a package length of 1.2 inches.

The photons from the night scene are focused by the pocketscope objective lens and strike the semi-transparent photocathode where electrons are emitted which then enter the small diameter microchannels (Figure 6). Each collision of the electrons with the wall of the channel causes an increase in electrons because of the secondary electron emission characteristics of the MCP walls (Figure 7). At the output end of the microchannel plate the electrons are proximity focused onto a phosphor screen and the electron representation of the scene is changed back into a visual presentation of the scene at a much higher light level. Typical luminous gain is fifteen thousand (foot lamberts/foot candle). The image inversion is accomplished

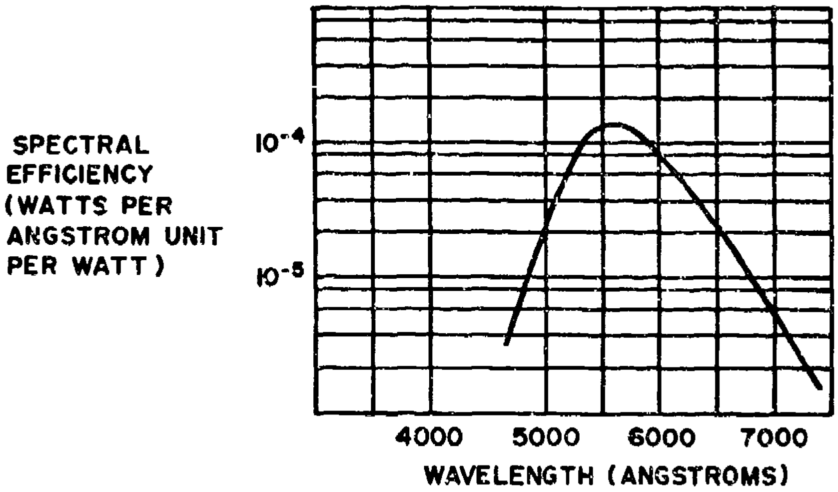


Figure 3. Phosphor--Converts the Accelerated Photo-Electrons Back Into Photons

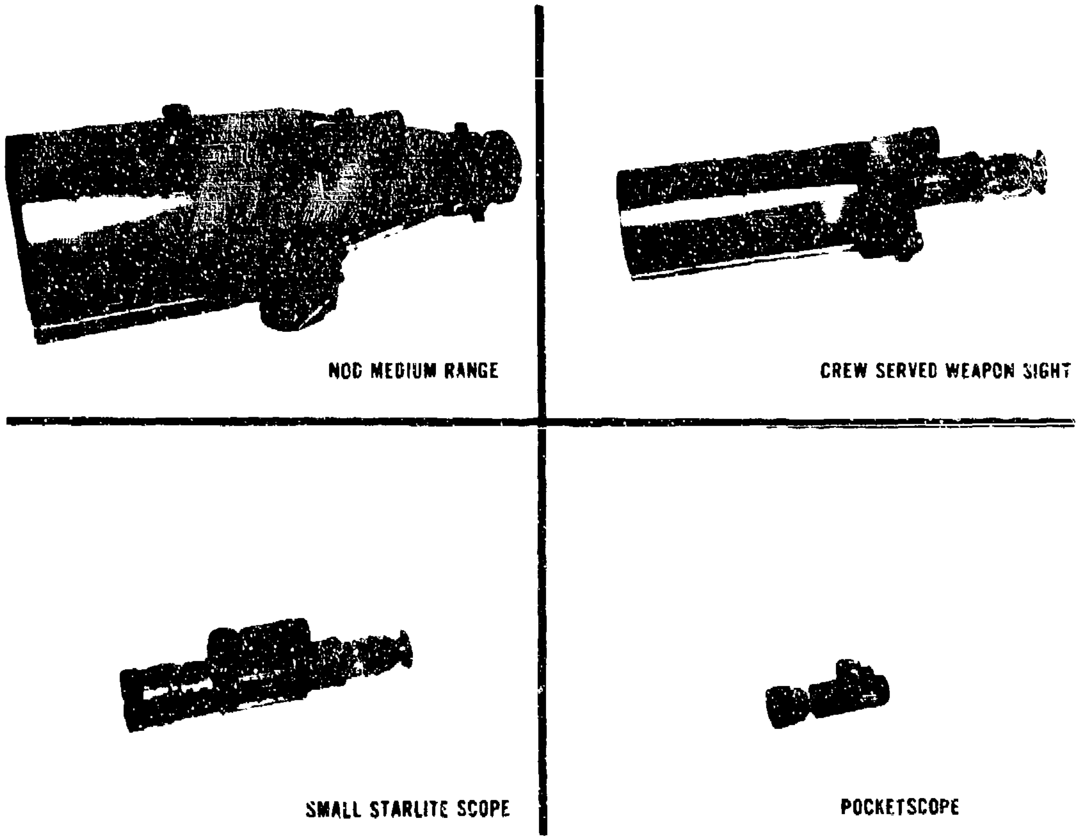
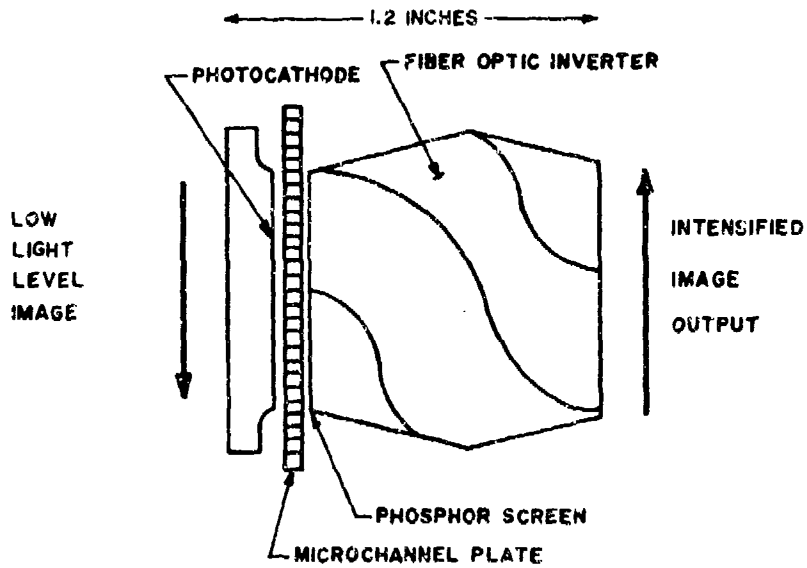
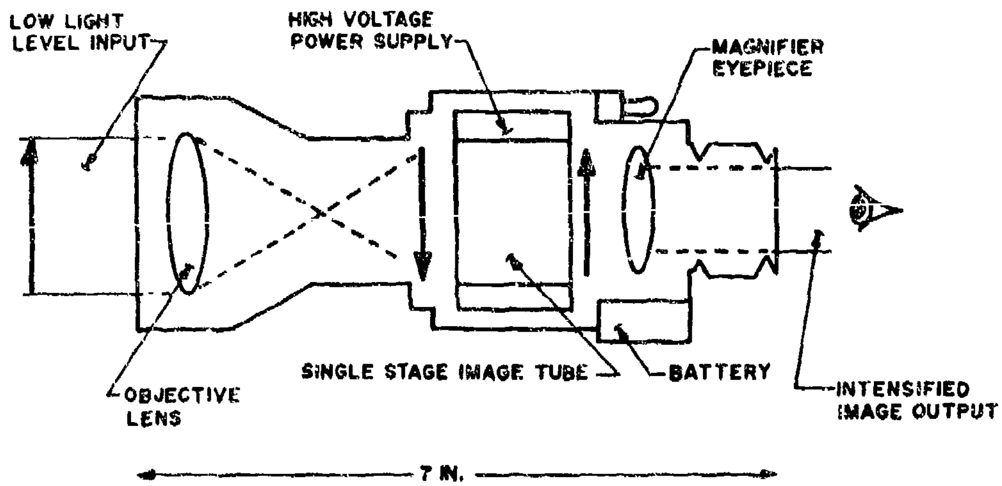


Figure 4. Family of Night Telescopes



SINGLE STAGE TUBE small size and weight advantages made possible by new microchannel technology

Figure 5. Microchannel Image Intensifier



A night telescope system designed around the single stage tube is indeed small enough to be called a POCKETSCOPE

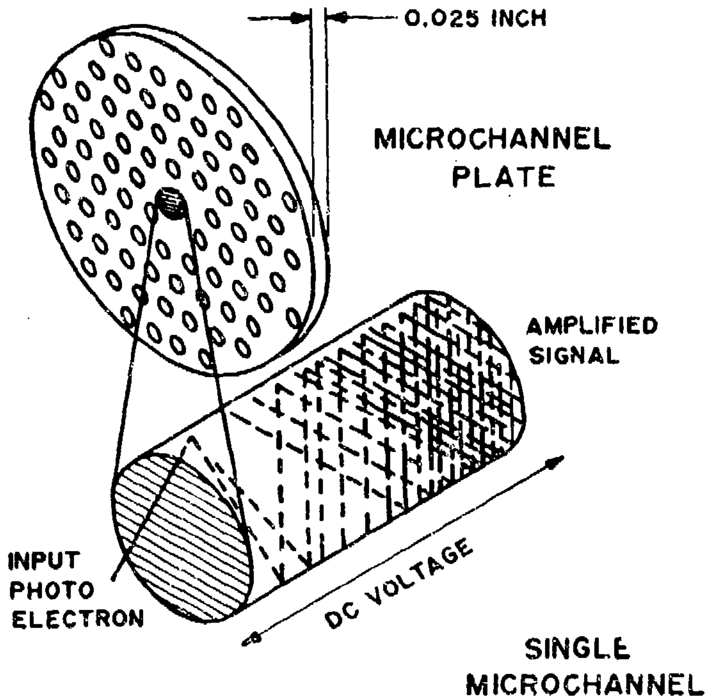
Figure 6. Night Vision Pocketscope System

by an 18mm format fiber optic inverter that rotates the real optical image 180° within a 19mm distance (Figure 8) and illustrates a novel application of fiber optics to provide optical inversion in a very short distance.

The microchannels are a remarkable advancement in the state-of-the-art when one realizes that approximately 1.7×10^6 microchannels are squeezed into a square inch and that the electronic gain takes place in a distance of only 0.025 inch. The photoemitter material used was an improved version of the S-20 used in the cascaded tube. The phosphor material was changed slightly so as to maintain the green color of the P-20 (Figure 3), but with longer time response so that the single stage tube matched the integration time of a cascaded tube. This integration time smooths out noise fluctuations in the single stage tube and therefore provides a clean image.

The high field potentials required by the tube are supplied by a recently developed high voltage miniaturized, wrap-around power supply. The power supply replenishes the electrons used in the secondary emission process and protects the tube from high light levels (Figure 9) by sensing the increased light level and automatically adjusting internal tube voltage. Note in Figure 9 that the screen brightness of the microchannel tube is much less than that of the three-stage tubes. This lower screen brightness causes the microchannel system to have slightly less search effectiveness, but it does allow the observer to regain his natural scotopic vision faster. In addition to power supply protection, the microchannel plate itself has a basic saturation curve as a function of light level. The combined effect of the microchannel saturation and the power supply is shown in Figure 9 by the comparison curves of both of the electron acceleration three-stage tube and secondary emission single-stage tube for several decades of light level. The microchannel saturation is a localized effect in that individual channels operate, essentially, independently of each other. Although there is a small amount of cross talk, this localized saturation greatly aids in improving "whiteout" image blooming that severely affects the electron acceleration three-stage tube. The blooming is not completely eliminated in the microchannel tube, but it is greatly reduced.

Figures 10 and 11 show a man target at a light level corresponding to starlight which has a bright source placed between him and the night vision device. The vastly improved performance of the single-stage pocketscope over the three-stage system is due to the aforementioned microchannel saturation and power supply protection. This feature means that performance of the pocketscope single-stage device will be much improved in the presence of bright sources like car headlights, campfires, and street lights. Note that in Figure 9 the three-stage device actually turns itself off in the presence of many bright sources and ambient light levels above twilight (approximately 10^1fc).



THE MECHANISM for amplifying the photo-electrons is the secondary emission of electrons within a 12 micron diameter glass channel.

Figure 7. Amplification of Photo-Electrons

Figure 8. Application of Fiber Optics to Optical Inversion

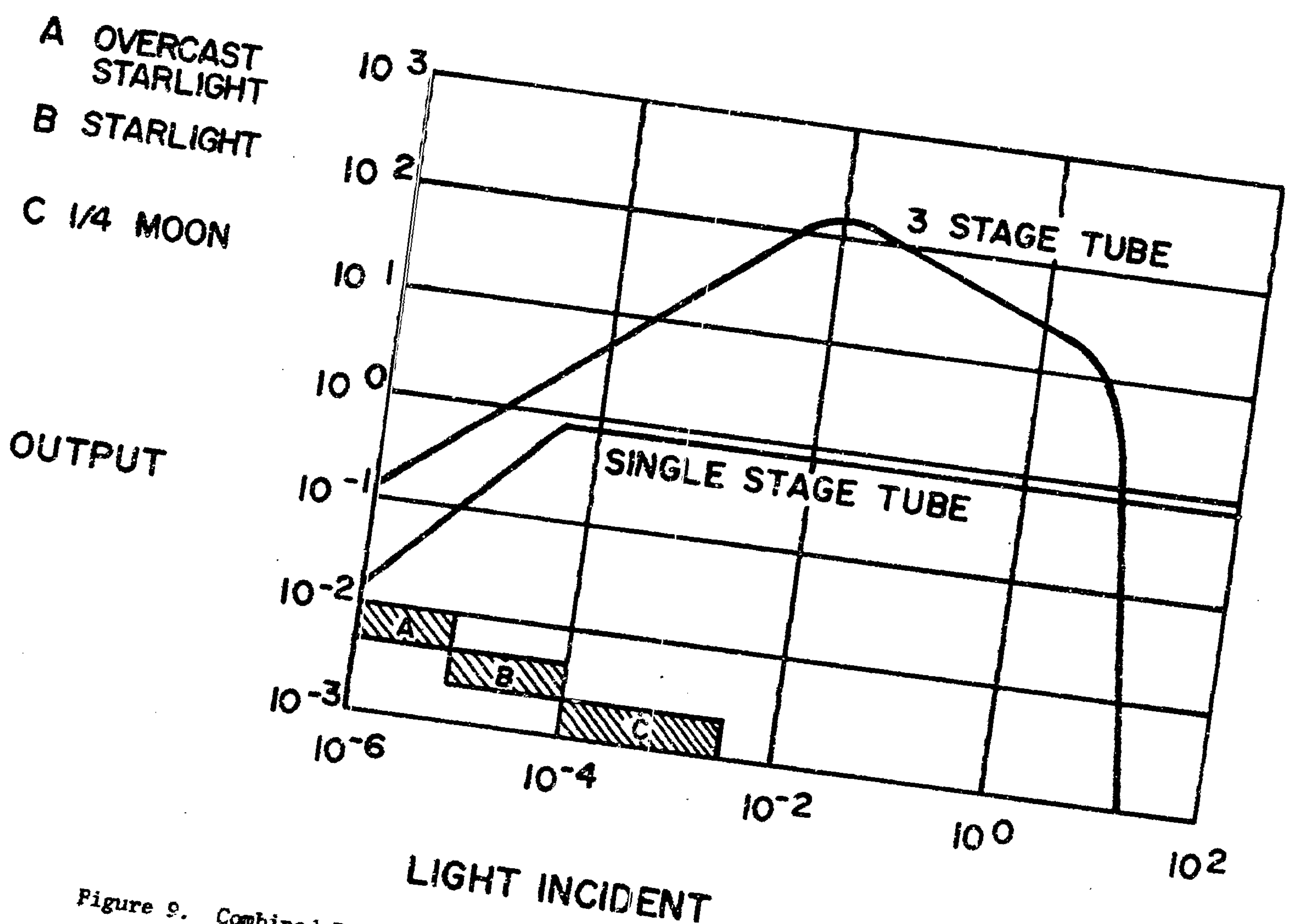


Figure 9. Combined Effect Curves of Microchannel Saturation and Power Supply

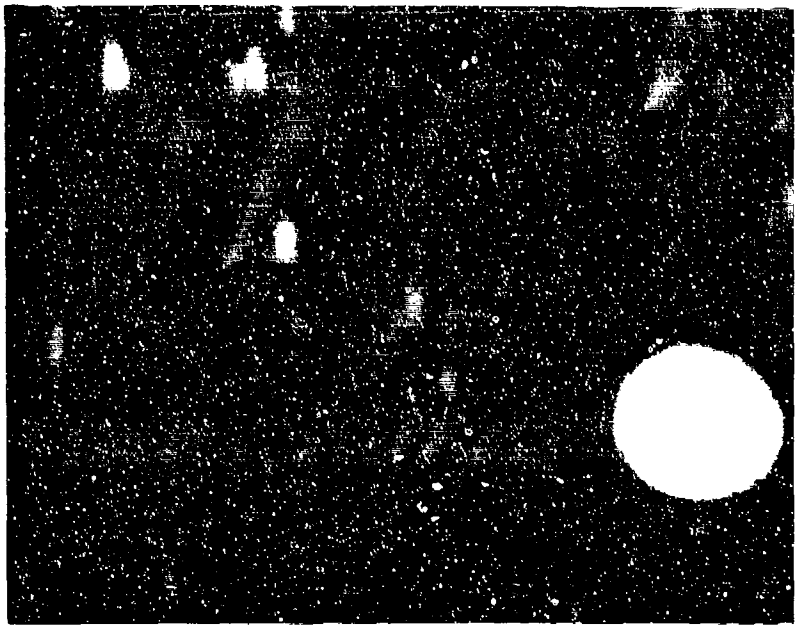


Figure 10. First Generation Starlite Scope

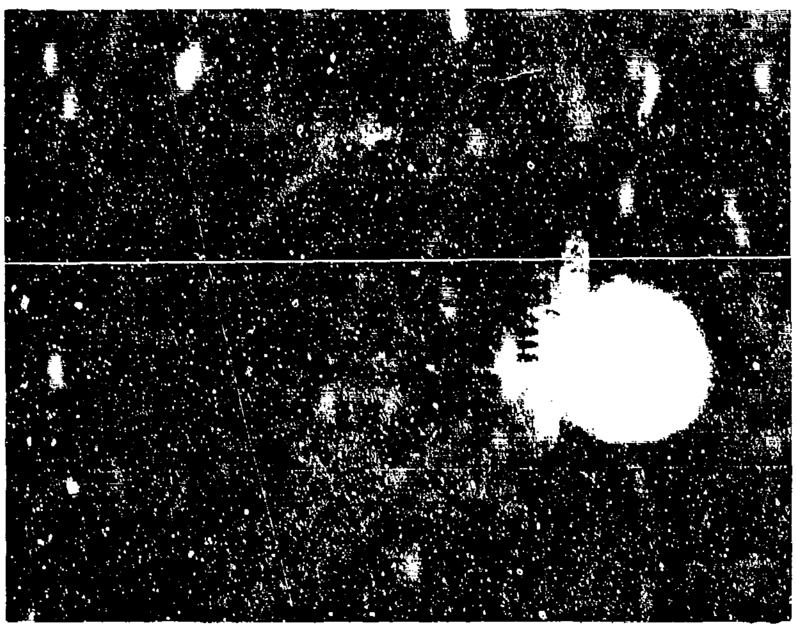


Figure 11. Second Generation Pocketscope

System Performance

The real worth of any night vision device is most clearly shown when it is compared to the most cost effective night vision device known--the dark adapted human eye. Shown in Figure 12 is the range performance of the single-stage pocketscope as compared to the unaided eye and to the three-stage device. The light level was 1.0 x 10^{-4} foot-candles; the target was a man; the background was trees and field; and the clutter was medium to heavy in this comparison. The unaided eye was allowed to dark adapt for 20 minutes, whereas the night vision devices were used instantaneously. The relative performance of the pocketscope and three-stage device is noteworthy in view of the fact that the three-stage device has an objective lens focal length of 135mm compared to the pocketscope objective lens focal length of 72mm. The size difference between the 1.5-pound device and the widely used 6.0-pound three-stage device is shown in Figure 13.

This single stage tube is easily used in a family of night vision devices wherein the systems designer merely exchanges the objective lens or eyepiece lens, depending on the intended useage of the device. For use under quarter moon light levels or less, care must be taken to have the objective lens design corrected for the spectral response of the photocathode. This interchanging of optics is done quite easily because the tube distortion is negligible and the input and output image planes of the tube lie on the surface of fiber optics, and one does not have to consider the optical path through glass typically used in previous image tube types. The fiber optic input and output also allow for other than flat planes to optimize the tube and optics interface. The dependence of range on the objective lens used is shown in the nomograph of Figure 14, where a 72mm objective lens with a T/number of 1.8 was chosen to show what the recognition range of a man-size target would be. The scene illumination was starlight and the reflectivity of the target was 40 percent. This range number assumes good atmospheric conditions (i.e., image intensifiers do not see through fog or smoke) and unobstructed line of sight.

Applications

Although the Pocketscope was primarily designed for military use, it is also ideally suited for many civilian uses because of its small size and improved performance in the presence of unexpected bright lights at night. Army testing has indicated great potential for night search parties, surveillance from helicopters and light aircraft, plant and office building security, and border patrol.

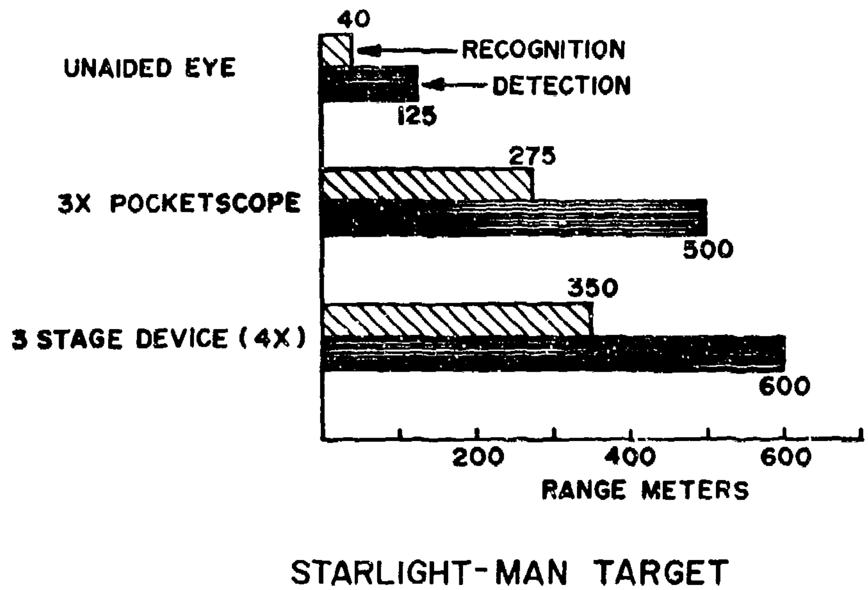


Figure 12. Single-Stage Pocketscope--Comparative Range Performance

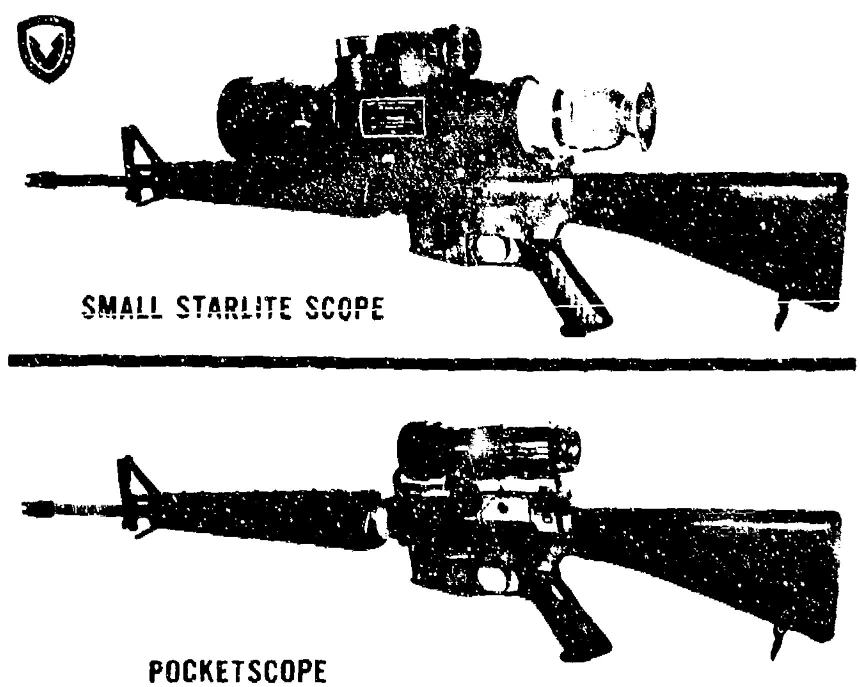


Figure 13. Comparative Sizes of Rifle-Mounted Small Starlite Scope and Pocketscope

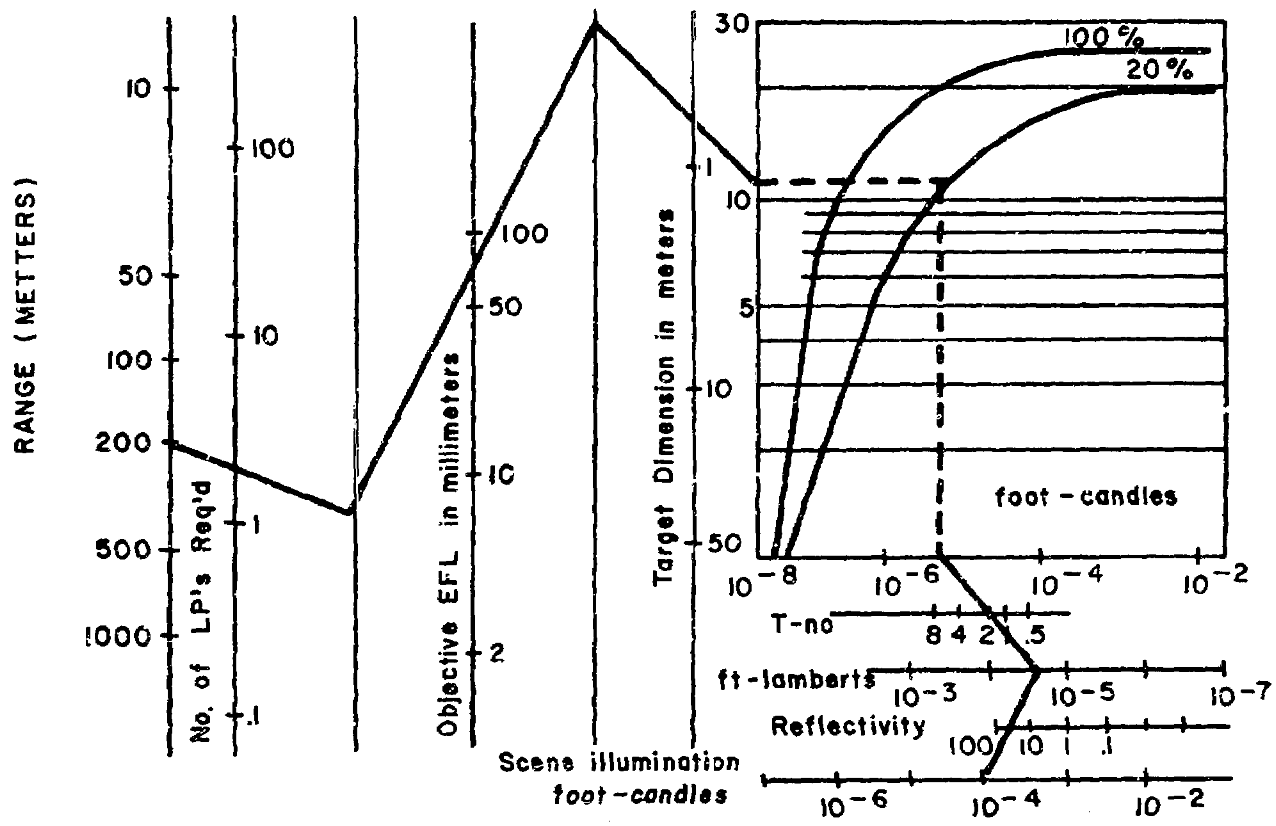


Figure 14. Range Nomograph--72mm Objective Lens

HANDHELD THERMAL VIEWER

By: Joseph J. Wiedmann, Night Vision Laboratory, USAECOM

The Handheld Thermal Viewer is a lightweight, passive thermal imaging system intended for surveillance at night. Evaluations have shown that the Viewer is capable of detecting personnel targets through light foliage, haze, and in complete darkness. These features, plus inherent properties which allow an infrared sensor to "see" small differences in temperature, make this device extremely useful in both military and civilian applications.

To elaborate briefly on the infrared phenomenon, all objects and persons emit thermal radiation in that region of the electromagnetic spectrum called the infrared region. This region is bordered by the visible and radio regions. Because this infrared radiation is beyond the visible part of the spectrum, these infrared waves, which are emitted both day and night, cannot be seen by the naked eye. Also, since IR radiation has longer wavelengths, it is not as easily blocked or absorbed by haze or smoke particles in the air as the shorter light waves are. Therefore, infrared radiation entering the viewer can be converted to create an image display of the temperature differences between the object and its background.

The Viewer was originally designed to allow a soldier to see the enemy before the enemy could see him. This was to be accomplished on the darkest night and under cover of thick forest overhead. These conditions limited the use of starlight scope-type devices, which in turn made infrared more attractive. The infrared principle is not new, but previous systems were heavy, bulky, hard to use, and took too much time to make a picture of the scene. However, recent advances in infrared sensors and cooling devices have made possible the development of the Handheld Thermal Viewer. The Viewer has a lead selenide detector array of 48 elements thermoelectrically cooled to about 200°K ([illegible]°F). The infrared waves, in the form of thermal energy or photons emitted by the targets, enter through the window, impinge on the scanning mirror, and are focused on the detector array by the optics (Figure 1). The detector converts the infrared energy into electrical signals which are then processed and displayed on a 1-inch cathode ray tube (TV tube) as a real-time image. The Viewer weighs 6 pounds and is powered by a belt-mounted rechargeable battery pack.

The primary use of the Viewer is to detect and recognize personnel targets at night, and it does this with amazing success. Personnel targets stand out so clearly that a man cannot be missed. This has been verified by Army test reports and by an evaluation by combat troops in Vietnam.

The Viewer has also been evaluated in the area of early detection of enemy swimmers approaching ships and bridges. A man can be spotted at a distance by the Viewer when any part of his body is above water. Integrated with SONAR, the Viewer can detect a swimmer above or below water. Other Army units are testing the Viewer's capability to see dogs at night through different terrain while in pursuit of a scent. They are also evaluating modified viewers for mine detection.

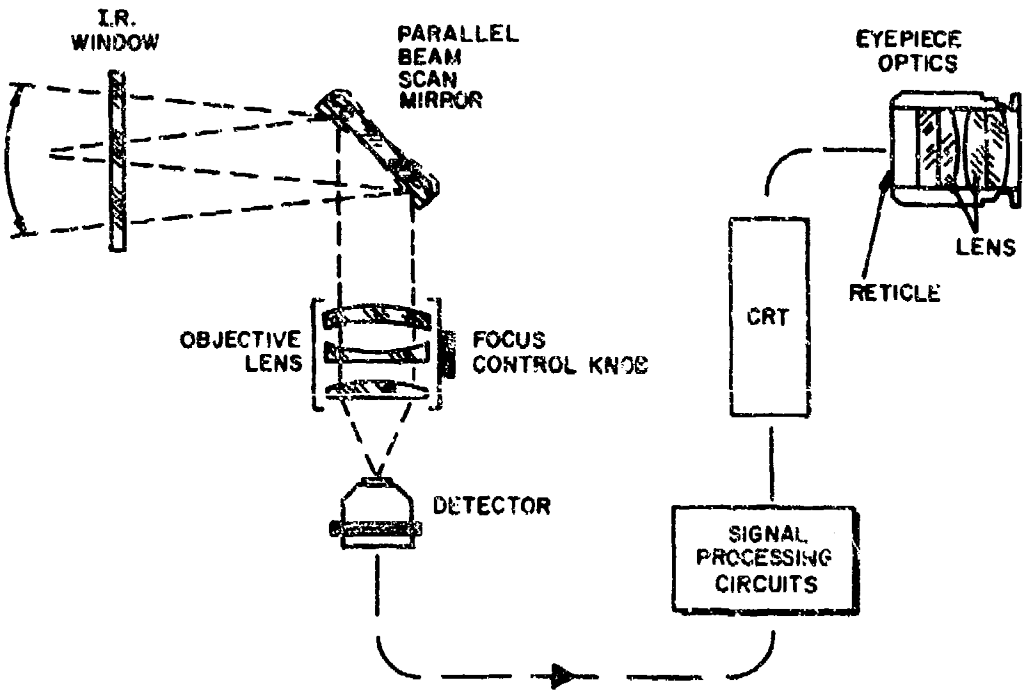


Figure 1. Schematic Diagram of the Handheld Thermal Viewer

Since declassification in 1971, the Viewer has been successfully used and evaluated in widely diverse civilian applications. The Park Rangers in the Everglades in Florida are now evaluating the Viewer as an aid in the detection and capture of animals and alligator poachers. They have used it on the ground and from the open window of a helicopter in searching for men or airboats. The hot engines of the boats can be readily detected in the swamp's underbrush, thus giving away its position.

The Bureau of Mines is using the Viewer in underground mines to detect loose and hazardous rock on mine walls and ceilings. More strikingly, a modified Viewer is contemplated being sent down through a narrow hole on a cable during a mine mishap to detect any miners who might be trapped in the shaft. The Viewer would penetrate the complete darkness and the smoky conditions. The mine would then be viewed with a TV type display at the surface.

In summary, the Viewer was originally intended for use by a soldier engaged in close combat or surveillance. It now provides a handheld thermal imaging capability to detect and recognize man targets from a real-time display. It is most useful in situations where low or no light, poor visibility, or camouflage restricts use of light intensifier devices. Since thermal energy in this spectral range of 3-5 micrometers is emitted from all objects, the Viewer is passive and does not require light of any kind. Because a man is warmer than the adjacent environment, he can be seen through the shadowed holes of light foliage (Figure 2), camouflage, or poor visibility such as haze or fog. The Viewer's detector is sensitive to very small temperature differences. For example, any changes made in an area, such as a hole that is dug and refilled, may be detected because there is a slight temperature difference between the disturbed and undistrubed ground. For more effective use in a perimeter defense, the Viewer can be used with a remote display. To amplify this application, studies are being made to incorporate a motion detection capability to the Viewer for this purpose.

Figure 2. Handheld Thermal Viewer Sharply Outlines Camouflaged Soldier (Bottom Photo). Photos of Same Area Taken Simultaneously by Camera (Top Photo) and Viewer (Bottom Photo).

STANDARDS FOR DETECTION EQUIPMENT

By: Robert Mills, Program Manager, Concealed Objects Detectors, National Bureau of Standards

In this first half of a two-part paper, I will discuss a new program at the National Bureau of Standards (NBS) called the Law Enforcement Standards Laboratory (LESL). In the second paper, Charles Smith will discuss one of the LESL projects dealing with the development of a performance standard for detection equipment using X-ray devices.

The principal mission of LESL is the development of national, voluntary standards for law enforcement hardware. These standards are intended to assist law enforcement officials in selecting and specifying their equipment. Manufacturers will also find these valuable in identifying the desired performance characteristics of the equipment they hope to sell.

Although LESL is part of the National Bureau of Standards, the program is sponsored by the National Institute of Law Enforcement and Criminal Justice (NILECJ or NILE), which is the research and development branch of the Law Enforcement Assistance Administration (LEAA). Figure 1 shows these inter-relationships. When LESL completes the development of a standard, it will be given to NILECJ for promulgation to police and other interested parties as an NILECJ standard.

The standards will include not only minimum requirements, but also test procedures for checking these requirements. The great majority of NILECJ standards will be performance standards rather than design standards. That is, the minimum requirement and test procedures will most frequently be expressed in terms of performance in order to encourage innovative approaches to hardware designs. Design standards will be written only for those cases where interchangeability is a paramount requirement.

The name "Law Enforcement Standards Laboratory" is somewhat of a misnomer in that LESL, per se, has no laboratories. Instead, LESL consists of a small central staff of program managers who utilize existing expertise and laboratory facilities to develop standards. To date, most of the work has been done by groups within NBS. However, it is anticipated that considerable work will be contracted outside of NBS where appropriate.

The functions of the two sections labeled "Standards Support Services" and "Testing Laboratory Evaluation" in Figure 2 are still being planned. The Standards Support Service will probably assist the sponsor with dissemination of information about NILECJ standards and their use. The Testing Laboratory Evaluation group will develop a coordinated system for compliance testing, by accredited laborato-

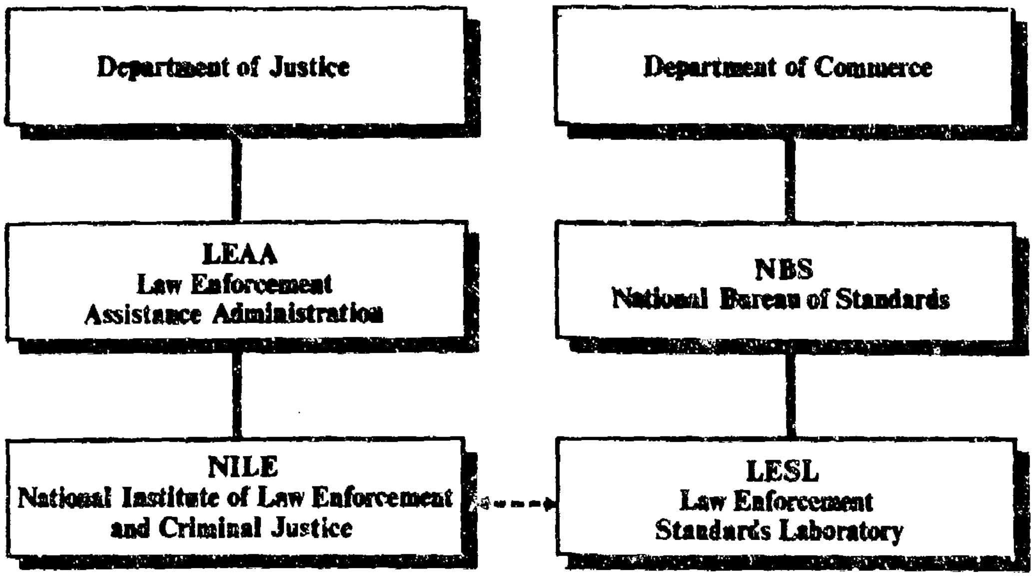


Figure 1. Inter-Relationships Between LESL in NBS and the Sponsor

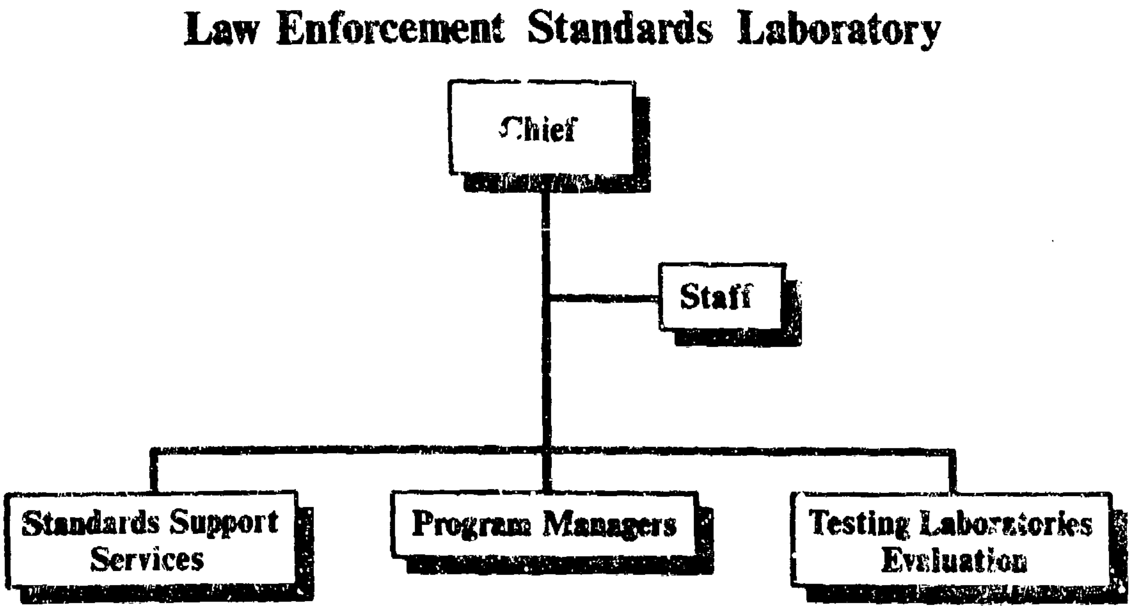


Figure 2. The Administrative Organization of LESL

ries, of law enforcement equipment. Further details of these two activities will be available when plans are completed.

The equipment has been grouped into eight program areas as follows:

1. Protective Equipment and Clothing, includes: body armor, shields, helmets, gas masks, uniforms, and fire, chemical, and water resistant clothing.

2. Communications Equipment and Supplies, includes: transceivers, telephones and intercoms, scramblers, p.a. systems, terminals, power supplies, and cable.

3. Security Systems, includes: surveillance and night vision devices, optical equipment, locks, grills, fences, safes, and alarm systems.

4. Emergency Equipment, includes: sirens, flashing lights, horns, spot and floodlights, occupant restraint systems, extraction equipment, ladders, fire extinguishers, and first aid equipment.

5. Concealed Objects Detectors, includes: dangerous drug, bomb and weapon detectors, breath-alcohol analyzers, fingerprint kits, and other evidence collection materials and devices.

6. Vehicles, includes: automobiles, motorcycles and scooters, snowmobiles, power boats, and aircraft.

7. Weapon Systems, includes: all lethal and non-lethal law enforcement weapons, such as firearms, non-poisonous gases, batons, and ammunition.

8. Building Systems, includes: institutional furnishings, equipment and supplies, building materials, and systems design.

Obviously, a crucial prerequisite for the development of good hardware standards is the compilation of user requirements. For example, we need to know the optimum practical compromises between wearer comfort and protection for body armor, false alarm rates and sensitivity for security alarm systems, etc. LESL Program Managers and NILECJ staff members have determined some of the more fundamental user requirements as a result of visits and personal contacts. NILECJ is experimenting with the use of questionnaires to obtain this information.

My program area, Concealed Objects Detectors, is probably of greatest interest to members of this meeting. Performance standards are currently being developed for quantitative breath-alcohol measuring devices* metal weapon detectors, and low intensity X-ray devices. We have hopes of initiating work in the near future to develop standards for pre-arrest breath-alcohol screening devices and field narcotic screening kits.

So far, I have discussed only standards for hardware. We are also studying the need, feasibility, and wisdom of other types of output, such as recommended procedures, certified reference materials, and standard reference data. Recommended procedures will not be represented as the only satisfactory procedure for performing a particular test, but as test procedures known to be reliable and thus useful to the less experienced. Recommended procedures are being considered in my program area for measuring alcohol concentration in blood, and for identifying narcotics. We are also considering making standard reference samples available to key state laboratories responsible for checking the accuracy of breath-alcohol analyzers. One of my colleagues at LESL has been asked to develop a type script exemplar atlas. Paint and glass chip collections have also been suggested.

Frankly, I hope to have the chance to discuss with some of you attending this meeting details of the needs you see for standards. I am anxious that our efforts complement any existing programs that other agencies or professional societies have undertaken in this area. Inquiries or comments will be especially welcomed. Our phone number is 301-921-3161 and mailing address is B-150 Physics Building, National Bureau of Standards, Washington, D. C. 20234.

Open Discussion

John Haben, Naval Ordnance Laboratory

Q. I think my question should be directed to Mr. Mills. When you buy on performance specification, it puts a rather high burden on the purchasing agency. Given a wide variety of local law enforcement agencies, that's a rather severe thing to do to these people. They are not really experts in this field. I know Mr. Smith touched on this problem, but I would think--what has been your experience?

A. That's a good question, but unfortunately, it is somewhat an open question at this time. I think there ought to be a central testing agency that performs qualification tests, and then issue a qualified products list to interested law enforcement agencies. However, plans for establishing a qualified products list have not yet been made.

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*Since May 1972, development of standards for breath-alcohol testing equipment has been sponsored by the National Highway Traffic Safety Administration, Department of Transportation.

Q. Really, what I'm saying is a performance specification is very fine, but it's really tough on the purchasing agency, regardless of who does the testing. It's a lot easier to purchase on a hard specification. I just wondered why you were set up to do it the other way.

A. Well...

Q. I realize that there is a large variety of equipment available.

A. The National Bureau of Standards encourages the use of performance standards to avoid the type of difficulties the building industry has with building codes. Often, building codes require the use of 2 x 4 lumber even though cheaper building materials may be available that could do the job better if only the code allowed. When possible, as it is with weapon detectors standards, it is desirable to use performance language to encourage the introduction of improved designs by the manufacturer. As you point out, the price which must be paid for the use of performance language is the increased difficulty in testing for compliance. Therefore, I believe a competent testing agency is needed which can perform qualification tests for all potential users, and circulate the results via a qualified products list. I do know that the National Institute of Law Enforcement and Criminal Justice is discussing this problem with the National Bureau of Standards, although detailed plans have not been worked out.

<u>Major Lodde</u>, U. S. Army Environmental Agency

Q. Will these standards be published in the Federal Register, or how will they be distributed?

A. When completed, they will be distributed by the National Institute of Law Enforcement and Criminal Justice. Probably the law enforcement agencies will eventually have a shelf full of these standards. If you are interested in getting into the review process, which we would very much welcome, then you ought to identify yourself to Mike Smith, Ken Yee, or me.

<u>Dr. Manley</u>, Navy EOD Facility

Q. There is a step before performance requirements and that's determining what the operational requirements are. How do you interface with all of the people who have vested interest in the type of equipment that you want to write the performance standards on?

A. I said a little bit about that when I talked about user requirements. We are going to try to get user requirements in several ways. One way will be through our talking to a number of knowledgeable law enforcement officials and identifying some of the user requirements.

The National Institute of Law Enforcement and Criminal Justice is setting up a three-prong program which they call the Equipment Systems Improvement Program. The first part of that program is what they call the Analysis Group. This Analysis Group will assist in identifying user requirements. Their information will be available to us. (We are the second group called the Standards and Guidelines Group. There will be a third group that's called the Development Group; they will develop new or modified equipment as needed.) The final step in the development of our standards consists of a fairly broad review of the document by interested outside parties. This review procedure will help to alert us to overlooked or incorrect user requirements.

STANDARDS FOR DETECTION EQUIPMENT--X-RAY SYSTEMS

By: Charles N. Smith, National Bureau of Standards

With support from the National Institute for Law Enforcement and Criminal Justice of the Law Enforcement Assistance Administration, the Applied Radiation Division of the Center for Radiation Research is developing performance standards for X-ray and radionuclide systems for use in the field of law enforcement. Two standards are currently being developed: "X-Ray Systems for Discrete Item Applications" and "X-Ray Systems for Screening Operations." I would like to discuss briefly some of the features of these two types of systems and some of the requirements for the standard on systems for discrete items.

There are at least two different use modes for X-ray equipment. One use is on discrete items; that is to say, on items that are highly suspected of containing explosive and/or incendiary contents. The requirements for an X-ray system in this case include high degree of portability and fast, informative results. Users of such equipment include bomb squad technicians who are responsible for handling, disarming, and disposing of such devices. Another use mode for X-ray equipment is in screening operations. Such operations can be either routine or emergency in nature. Activities falling into this type of work include inspection of briefcases and handbags in critical areas of public buildings (e.g., courtrooms) and the checking of large numbers of packages in post offices and transportation systems and on common carriers such as airplanes. The low intensity X-ray equipment in a screening operation is really used as a culling tool. Items suspected by the X-ray system operator are weeded out for further inspection. Requirements for such an X-ray system include low exposure to screening operation personnel and no radiation damage to the items or contents. Development of X-ray systems during the last few years has concentrated on these two aspects of the problem.

Now, I would like to discuss some of the requirements for the standard on X-ray systems for discrete item applications. The system should be safe for the operator, not only from the standpoint of radiation, but also from the standpoint of fire and shock. Another requirement relates to the bomb squad technician who must get fast, highly reproducible, informative results, since he doesn't have a lot of time to adjust the system or to wait because of film-development problems. Other requirements have to do with portability and ruggedness. Earlier today, Ralph Miller covered several other requirements for X-ray systems insofar as EOD activity is concerned. These performance requirements are qualitative statements of what you want a system to do. What one tries to do in developing a performance standard is to select those system characteristics on which measurements can be made and which will cover user needs. A performance criterion represents a quantitative level that is assigned to a given requirement, and the system is measured and compared according to a given test method and procedure to see if the requirement is met. For example, in satisfying the user requirement on safety, one of the things that would be covered would be radiation leakage. The question of scattered radiation came up earlier in Mr. Miller's talk. This is, indeed, a problem because, as far as EOD work goes, scattered radiation is not constant since surroundings are different. But, we can say something about radiation leakage in the performance standard. This statement would be in the form: Radiation emitted from the tube head assembly shall be less than one roentgen per hour at one meter when the unit is operated at its leakage technique factor. There will be in the standard a section which contains the test method and procedure for making leakage radiation measurements.

It was previously stated that the bomb squad technician must be provided with fast, highly reproducible, informative results. This comes under the general topic of image quality, which is one of the main requirements an EOD person is concerned with. The thickness and inherent sensitivity tests will be used to check image quality. Beam quality/quantity will also be taken into account. The image quality requirement covering the thickness sensitivity aspect would read as follows: The X-ray system shall be able to penetrate a certain thickness of steel and show a certain diameter wire in all orientations of the radiographs. The two image quality tests are designed so that the bomb squad technician (user) can perform them easily to see if the X-ray system complies with the image quality requirements. The materials needed for such tests are not expensive and are easy to secure. The test pattern is easy to construct when instructions are followed in the standard.

What I've presented this afternoon should give you some indication as to the type of activity each standard covers, and what to expect in the way of performance requirements and criteria for the standard concerned with X-ray systems used by bomb squad technicians on discrete items.

IR GUNFLASH DETECTION

By: Gerald Gallagher, Intrusion Detection Division, CM/CI Department, USAMERDC

In the Crowd Surveillance program we would like to be able to detect a weapon before it has been fired. However, this is not always feasible. The second best approach is to determine rapidly the location from which a weapon has been fired. Therefore, MERDC is investigating a gunflash locator called the Vehicular Equipment Gunflash Infrared Locator (VEGIL).

Figure 1 depicts a typical application--a parade situation where the area of surveillance is constantly changing. A vehicle equipped with the gunflash locator would proceed the car containing the "key figure" being protected. If a gunflash were detected, knowledge of the direction from which the gunflash occurred would aid in the quick apprehension of the sniper. The system could also be used by police or National Guard forces in riot areas where snipers might be present. Since the detector can be used while the vehicle is stationary, it would be suitable for political rallies, etc.

Stringent requirements exist for a gunflash detector which is to be used in an urban environment. The detection probability must be extremely high since, more than likely, a limited number of shots would be fired. False alarms must be minimal to insure operator confidence and to prevent inconveniences to the "key figure" being protected.

The system, which is being designed by Barnes Engineering Company, is an extension of similar systems developed for use on helicopters in Southeast Asia. MERDC evaluated one such system which had been modified for use on a car. Based on that evaluation, MERDC wrote requirements for the present system which stressed system resistance to false alarms and which required detection of weapons at ranges up to 1,000 feet.

The system consists of a roof-mounted optical head containing the basic detector elements, optics, and the microphone for an acoustic subsystem. The optical head assembly defines 48 individual fields of view which permits the direction in which the gunflash occurs to be determined within ± 10 degrees vertically and ± 15 degrees horizontally. The total coverage is 360 degrees in the horizontal direction and 80 degrees in the vertical direction. Located in the car trunk is the processing unit which contains the power supplies, amplifiers, and logic circuits. A readout assembly is provided that gives an aural alarm and a visual indication of the direction from which the gunflash occurs. (See Figure 2.) Normally the readout would be located in the back seat of the car; however, provisions are made for using the readout up to 20 feet from the car.

The VEGIL uses a "two color" approach to discriminate a gunflash from sunglint. A sunglint contains more energy in the visible region of the spectrum, whereas a gunflash contains energy in the infrared region. Figure 3 is a typical gunflash signature as "seen" by our system in the infrared and visible regions. By using two detectors, one in the infrared and one in the visible region, simple logic may be used to discriminate between gunflashes and sunglints.

Many other methods are being incorporated to minimize spurious sunglint signals, the chief cause of false alarms in the previous system. The electrical bandpass is tailored to give maximum response to pulse signals of the typical duration of a gunflash. In addition, there is a pulse width discrimination circuit which rejects pulses which are not characteristic of a gunflash width.

By using the above techniques, the goal of less than one false alarm in an 8-hour operating period should be met. Figure 4 is a block diagram of the system. This is a tentative design which may change as the program progresses. A breadboard has been built and was used to collect data on both gunflash and background noise. A feasibility model will be delivered to MERDC in late 1972. Based on a successful evaluation, field hardware could be ready in 1977. If an urgent need existed, field hardware might be made available within the next year.

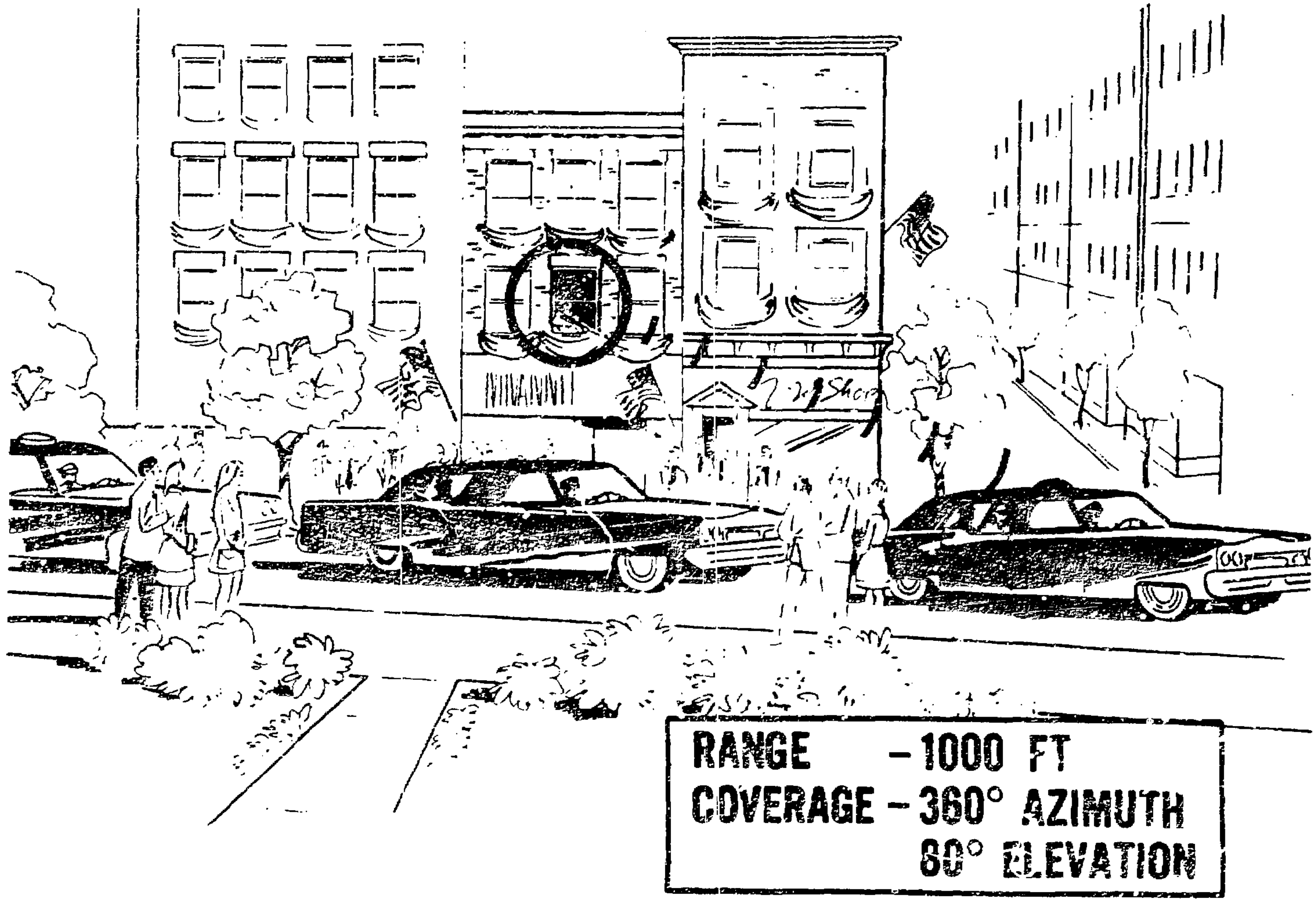


Figure 1. IR Gunflash Detector--Parade Situation

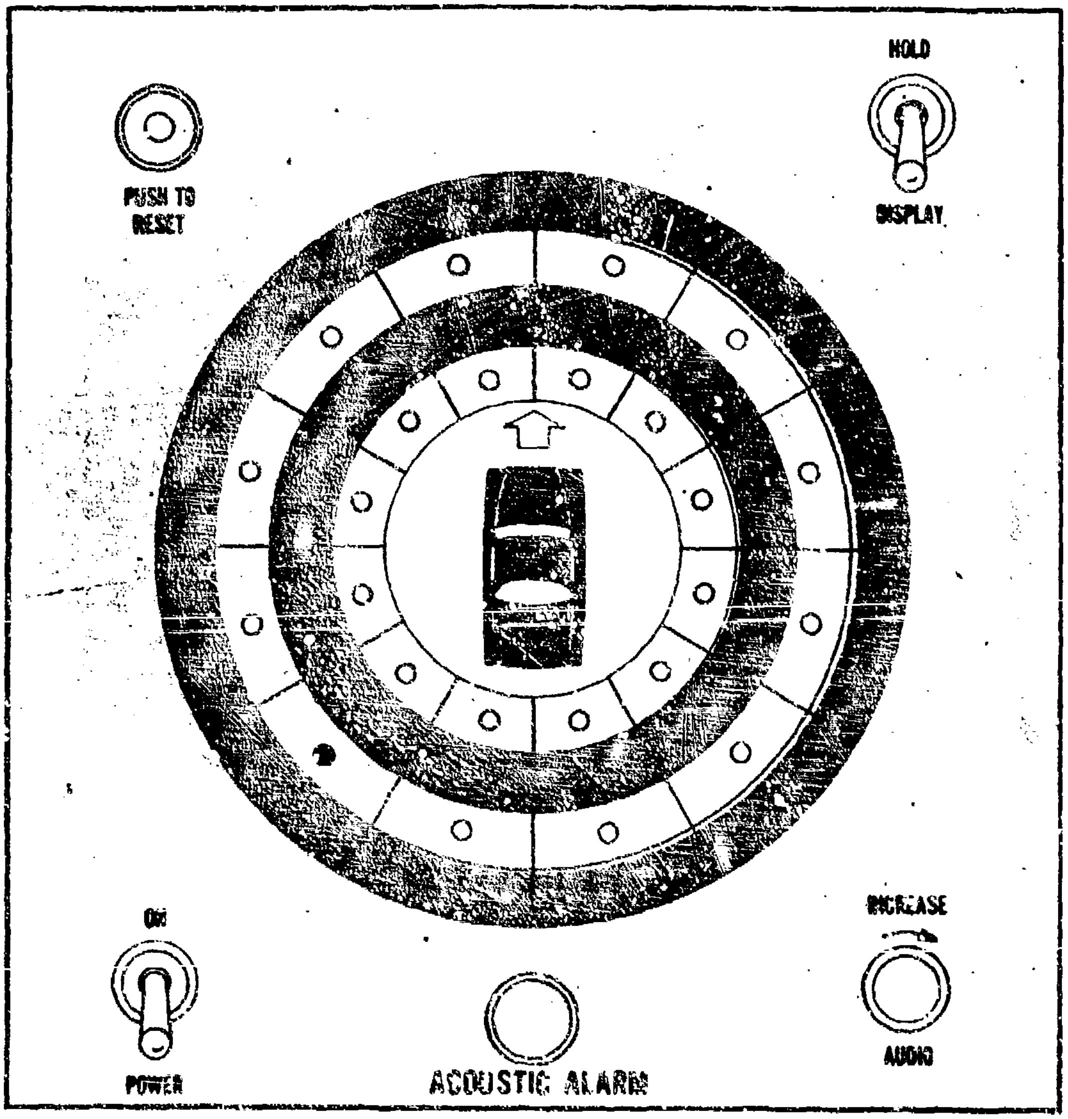


Figure 2. IR Gunflash Detector--Readout Assembly

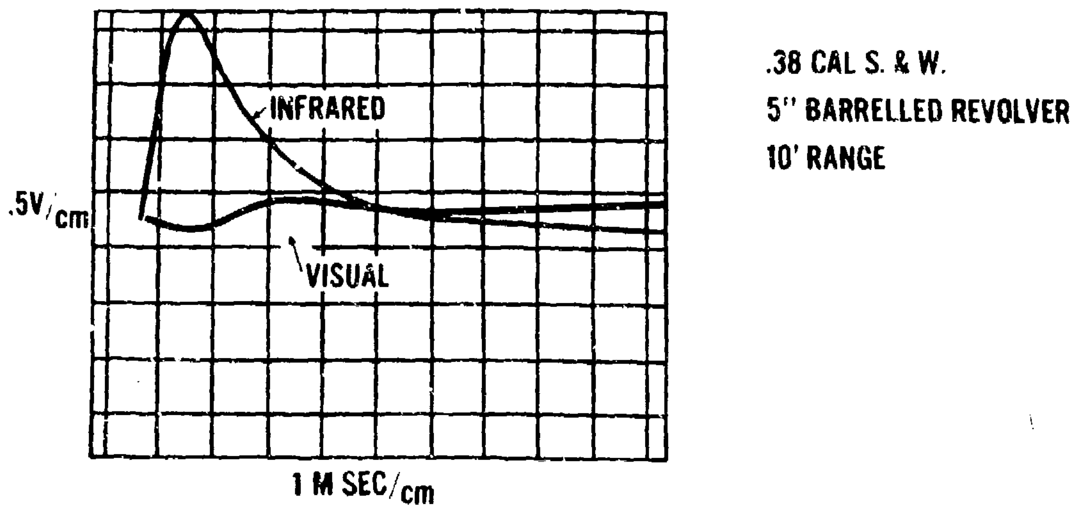


Figure 3. Typical Gunflash Signal

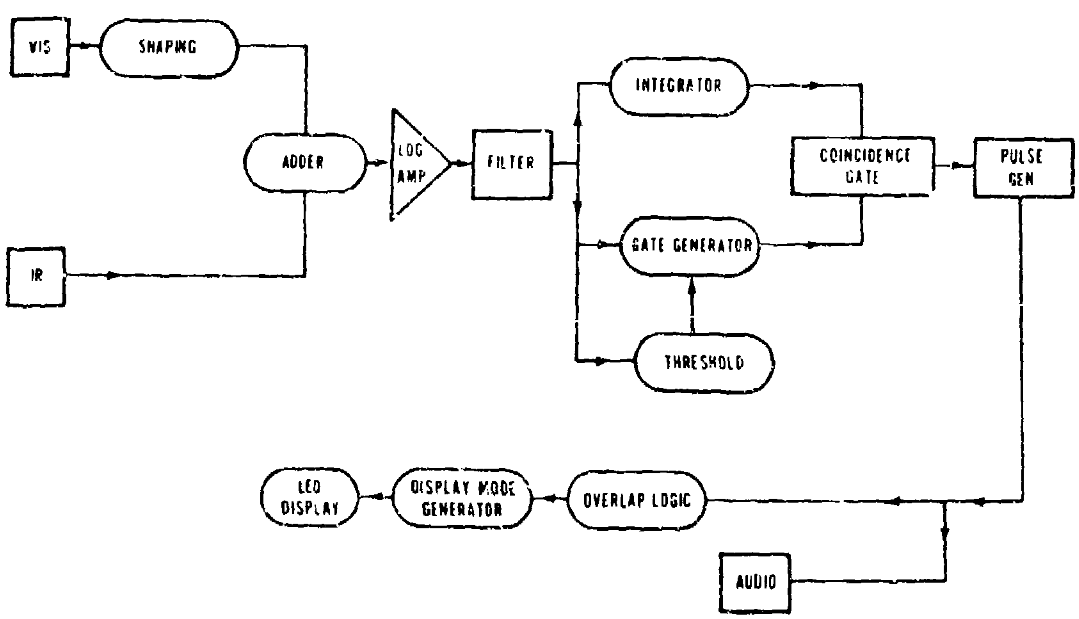


Figure 4. VEGIL Block Diagram

INTRODUCTION TO MINE DETECTION R&D EFFORTS RELEVANT TO PROTECTION OF PUBLIC FIGURES

By: Dr. Karl H. Steinbach, Mine Detection Division, CM/CI Department, USAMERDC

About 18 months ago, MERDC was designated the lead laboratory for all countermine efforts within the Department of the Army. As a consequence, we have substantially stepped up our R&D efforts in the area of mine detection. Aside from specific hardware developments, we are now more than ever emphasizing research directed towards the detection of the explosives content of mines--a problem that is very closely related to the protection of public figures.

MERDC has a long history in this research area, but past efforts have traditionally been hampered by inadequate funding and the lack of active support by others. Today, the situation is quite different. The increased staff of researchers and the improved laboratory facilities here at MERDC, the active participation by other government laboratories, and the significant advances in the state-of-the-art have made our efforts that much more promising. In addition, the paramilitary threat in urban environments, the drug problem, hijacking, and the new emphasis in pollution control have all helped to close the ranks between the various government agencies and private industry in meeting the common objectives.

We can take as an outstanding example the rather dramatic technological advances in the area of trace vapor detection. The concerted efforts of the U.S. Army, the Department of Transportation, NASA, local governments in the United States, and foreign governments, such as Israel and the United Kingdom, have generated an active commercial interest in this technology that we never enjoyed before. During the past few years, the detection sensitivity of prototype detectors has been improved by order of magnitude, and the detection of explosive trace vapors has become a reality.

This morning we will present only those selected topics of our mine detection efforts which we feel are directly related to your problem. Indeed, some aspects of the R&D efforts to be presented are specifically directed towards and funded for the protection of public figures. This afternoon you will see a demonstration of our explosives detection dogs. There are, of course, numerous other mine detection tasks which will not be discussed this morning. Let me only mention the highly sophisticated microwave detection systems under development--research in microwave holography, and signal processing and display techniques that offer the potential of locating artifacts in opaque media by 3-dimensional imaging.

Our doors are wide open. I hope that the presentations will stimulate further continued discussions in areas of mutual interest and thus pave the way for additional collaborative efforts. The first speaker from the Mine Detection Division is Maryland Kemp who will present the current status of trace gas detection.

EXPLOSIVE TRACE VAPOR DETECTION

By: Maryland D. Kemp, Mine Detection Division, CM/CI Department, USAMERDC

Background

This presentation is about detection based on gaseous effluvia. The detection applies generally to almost anything--explosives, mines, people, trucks, general military or civilian activity, etc. The discipline detects their presence or it indicates their absence. The absence or presence of detectible effluvia is based on the vapor pressure or the activity of the species sought. For example, the vapor pressure of TNT at 25° C is estimated to be of the order of 10^{-6} torr, and this requires that at equilibrium the concentration of TNT vapor in the circumambient atmosphere be approximately one part in 10^{11} (gms/cc). Detectors for effluvia emanating from TNT must have at least this sensitivity.

Trace Gas Detection Techniques

Principle: Trace gas detection divides itself into two main categories: (1) trace or ultratrace gas detection in the parts per million (ppm) or parts per billion (ppb) range; and (2) trace gas detection in the parts 10^{11} and better range. The latter category is required if detection of TNT-based explosives (10^{-6} torr vapor pressure at 25° C) is to be accomplished under ambient and non-equilibrium conditions. For other explosives, such as RDX, equilibrium vapor pressures of 10^{-9} torr or better at 25° C place still more stringent requirements on the limit of detection. In addition, under field conditions equilibrium does not exist and explosive detectors will need limits of detectability of the order of a thousand times that required for equilibrium conditions.

Looking at problems in general, the observation can be made from Figure 1 that trace gas detection or microanalysis has made steady and considerable progress instrumentwise during the last 30 years. Line A shows how the detectability limit, in atoms, has decreased during the last 30 years by a factor of 10^{18}. Line B shows the corresponding decrease in the sample size required in atoms, for detection during the same time span. This change is of the order of 10^{15}. In general then, the absolute amount that is detectable has decreased and the sample size required to detect this amount has decreased. This represents the progress of microanalysis during a definite time span and suggests also what one should expect in some future similar time span.

Figure 2 shows the present day sensitivity of microanalytical methods in terms of sample size. The unit here is in grams, with the ion probe as little as 10^{18}gms detected. Some methods, like the

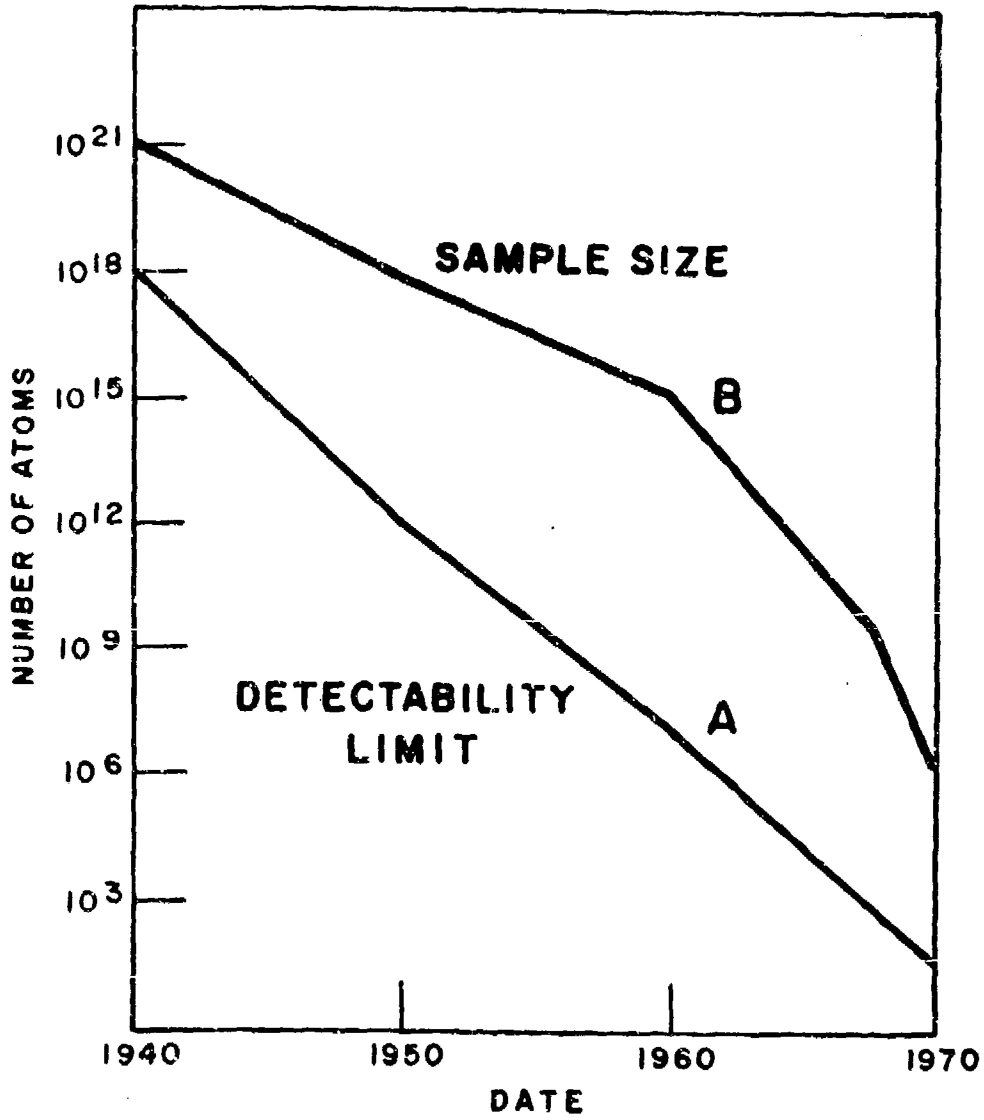


Figure 1. Trace Gas Detection Analytical Progress - 1940-1970

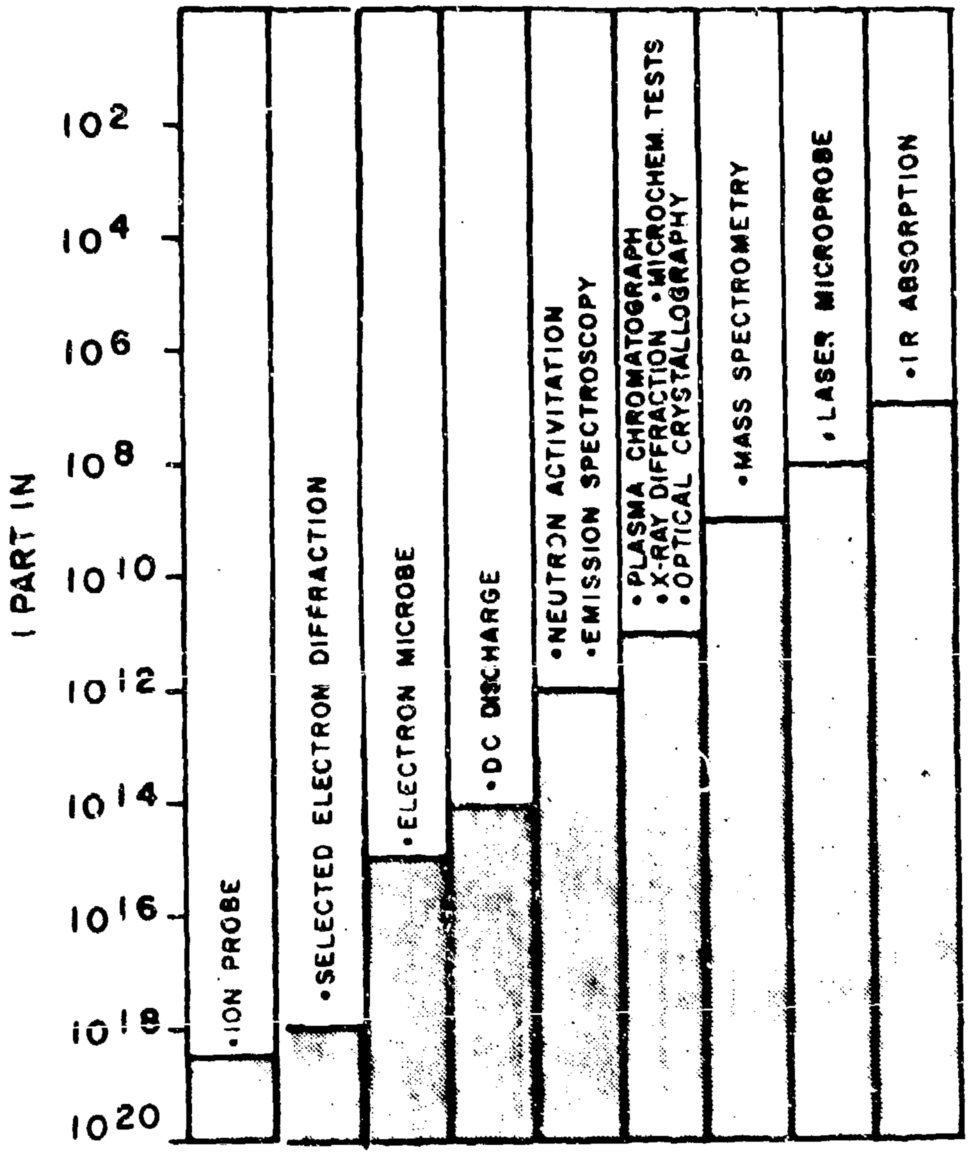


Figure 2. Comparative System Sensitivity

ion-emission electron microscope, will analyze single atoms, but only in certain metal samples in a special geometrical configuration. Current MERDC trace gas detection methods concentrate on those sensitivity areas in the lower portion of the line. These data represent the current progress achieved by instrument technology for all methods as of the present date. All of these are not adaptable to the compounds of immediate interest to us, but they do suggest more progress in sensitivity and specificity at a later date.

It has been indicated that biological specimens offer possibilities for detection. A simplified pictorial representation of biological detection capability is shown in Figure 3. You will notice that the most sensitive biological specimen is the moth. Implicit in these observations is the fact that under ideal conditions between target signal and detector these sensitivities can be reached. Also implicit in these observations is the fact that greater progress in instrument detection can be expected with certainty, while progress in biological detection cannot be made with the same certainty at the present time.

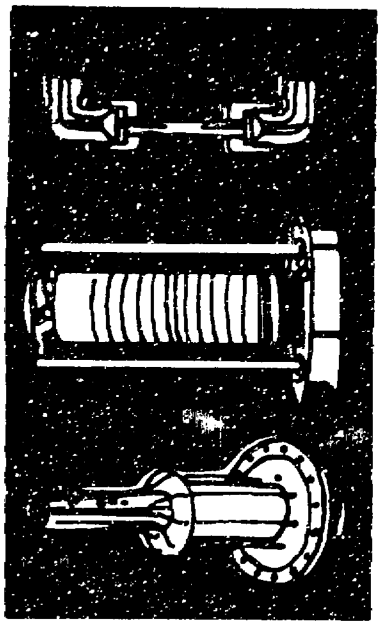
Detection Methods

There are about 20 parameters of elements, functional groups, or compounds known that can be incorporated into 15 or 20 detection systems which represent approximately 95 percent of all present-day detection systems. In this regard, analytical instrumentation useful for detectors is as follows:

- Thermal Conductivity
- Adsorption Spectroscopy
- Emission Spectroscopy
- Fluorescence Spectroscopy
- Hydrogen Flame Ionization
- Radioactive Ionization
- Ionization Breakdown
- Mass Spectrometry
- Nuclear Magnetic Resonance
- Polarographic Analysis
- Coulometric Analysis
- Colorometric Analysis
- Light Scattering
- Electrical Conductivity
- Differential Thermal Analysis
- Thermogravimetric Analysis
- pH Analysis
- RF Acoustical Analysis

The above must detect explosive effluvia in concentrations as shown in Tables I and II. The sensitivities for some of the best current commercially available trace gas detectors are shown in Table III.

SENSITIVITIES FOR MEASUREMENT OF TRACE ODORS IN AIR



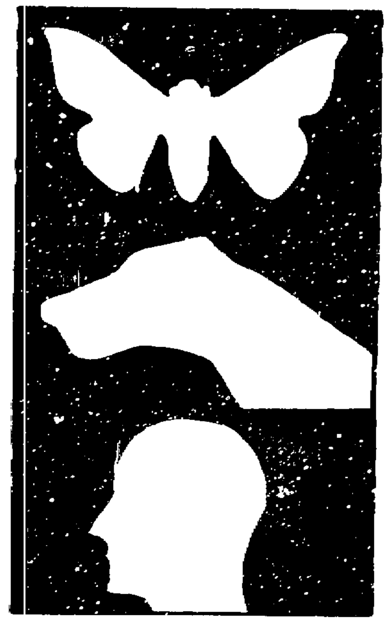


Figure 3. Comparative Instrument and Biological Detection Capability

TABLE I

EFFLUVIA FROM TYPICAL EXPLOSIVE INGREDIENTS

Substance	Vapor Pressure mm Hg (25°C)	Concentration In Vapor Phase (gms/cc)
TNT	$\sim 10^{-6}$	6 Parts in 10^{11}
DNT (2,4)	1.6×10^{-2}	6 Parts in 10^{7}
PETN	4.0×10^{-11}	1 Part in 10^{16}
MNT (1,4)	3.3×10^{-2}	4 Parts in 10^{7}
RDX	1.1×10^{-9}	1.34 Parts in 10^{15}

TABLE II

TYPICAL EFFLUENTS OF MAN OCCURRING IN MORE THAN TRACE QUANTITIES

Effluent	Vapor Pressure mm Hg (25°C)	Source
Cholesterol	0.1	Saliva
Citric Acid	0.1	Urine
Valine	0.1	Feces, sweat, urine
Lysine	0.1	Feces, urine, sweat, saliva
Mycin	0.1	Saliva
Leucine	0.1	Feces
Pyruvic Acid	1.3	Sweat, urine
Urea	0.1	Saliva, urine
Ammonia	gas	Urine, breath, sweat
Fats	0.01	Feces
Hydrocarbons	0.01	Sebum

TABLE III

DETECTION LIMITS FOR SELECTED G. C. DETECTORS

Thermal Conductivity	5 Parts in 10^{5}
Hydrogen Flame Ionization	1 Part in 10^{8}
Electron Capture	1 Part in 10^{7} to 1 Part in 10^{9}

Of particular interest are selected systems that have been extensively developed during recent years. These are:

Mass Spectrometry
Plasma Chromatography
Vapor Trace Analyzer
Bioluminescent Sensors
Chemiluminescent Reactions
The Condensation Nuclei
DC Discharge/Spectrometer

Some are now offered commercially. A discussion of these detectors and their operating principles follows.

Mass Spectrometry

In a mass spectrometer, gaseous molecules at low pressures are introduced into a vacuum, fragmented and ionized by a stream of electrons, assorted magnetically according to charge-to-mass ratio, and detected electrically as they are collected by an electron multiplying detector. New mass spectrometers, known as quadrupole mass spectrometers, have recently been developed as part of the space industry, which satisfy portability requirements for trace gas detection and which use radio frequency quadrupole fields to sort out the ions of different masses. The application of mass spectrometry to trace gas detection requires preliminary separation of effluvia from the environment by means of semi-permeable membranes, gas chromatography, or fast direct sampling valves. Of these three types of introduction systems, the semi-permeable (Llwellyn) membranes have provided only moderate success. Gas chromatography needs preconcentration and is not capable of operating in real time (retention times for explosive materials are typically in excess of 15 minutes). Fast sampling valves are still under investigation. Despite difficulties in each of these areas, programs are being initiated at MERDC which will allow a closer look at each of these problem areas.

Plasma Chromatography

In plasma chromatography, ions, formed with the aid of a Ni-63 radioactive source, are passed through a time-of-flight drift tube where they are separated according to mobility by alternating electric fields. The detection is made at atmospheric pressure and the device is capable of detecting concentrations near one part in 10^{10} for TNT (Figure 4). Sensitivity is far too low for detection of TNT trace vapors under ambient conditions in the field. The plasma chromatograph has been coupled to a Finnigan Model 1015 quadrupole mass spectrometer so as to allow constituent identification of multicomponent samples.

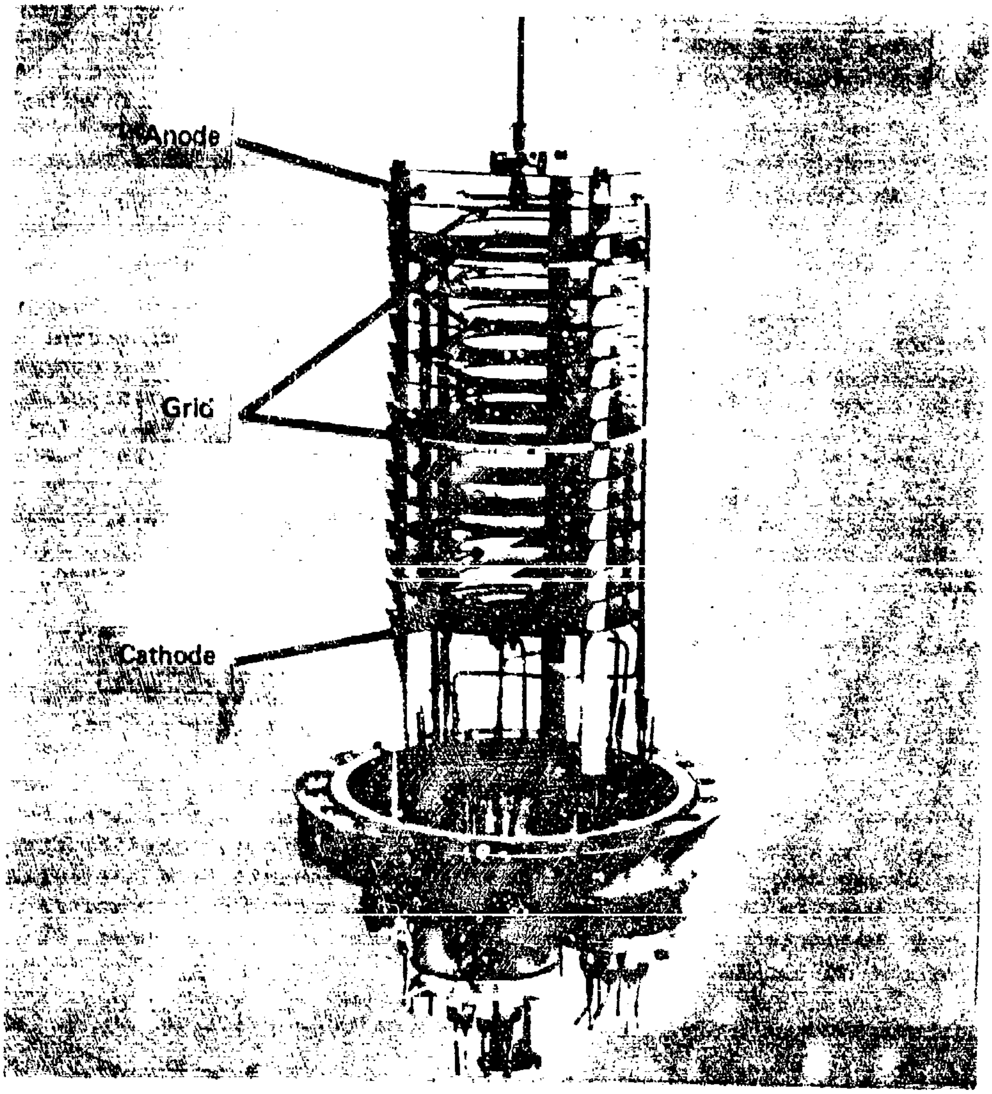


Figure 4. Plasma Chromatograph® Sensor Head

Vapor Trace Analyzer

The Vapor Trace Analyzer is a commercially available instrument. It was developed by the Israeli and is now being marketed in the United States. It incorporates an electron capture detector in combination with a gc separator and a unique sampling system which concentrates the sample (4000-1) prior to detection. The instrument has been purchased by MERDC and is now under evaluation. It is reported that with the preconcentration attachment it detects TNT vapor. MERDC is trying to confirm this. More evidence is available regarding its ability to detect dynamite.

Bioluminescence

Some consideration has been given to bioluminescence as a vapor detection mechanism. In these studies, a culture of a luminescent microorganism growing on the surface of a suitable matrix was considered an elementary type of chemical vapor detector. Bioluminescent detection technology has been investigated and directed towards the development of potential sensors responsive to humans. It has been reported that the response of the luminescent microbial sensors to various concentrations of human effluents in the sampled environment was an instantaneous change of their constant light intensity. Sensitivity or detection limits and specificity were not established. Subsequent preliminary observations have been made on the use of microbial sensors for the detection of explosives. MERDC laboratory tests conducted on TNT, on MERDC composition B, and on RDX--interspersed with methanol, xylene, and acetone--with selected microbial sensors elicited a positive reaction of the sensors when air was drawn over the explosive samples and into the instrument. For TNT and for composition B, a small amount of heat (not above 100° C) was required for a significant signal. The response was not negated by passage of the toxic vapors over the selected sensors. Specificity, limit of detection, and the influence of interferants were not established. Further experimental work is under way by MERDC to assess the real potential of the bioluminescent detector for personnel or explosives detection.

Chemiluminescence

The term chemiluminescence designates the emission of visible light without sensible heat as a result of chemical reaction. As applied to exudates, the vast majority of chemiluminescent agents involve oxidation reactions and apparently involve the origin molecule. This property makes this instrumentation technique promising because the reaction site for bioeffluents will be in the immediate vicinity of the person or activity towards whom the detection is directed. Firm agreement does not exist on the optical parameters for chemiluminescent systems. A method for detecting effluvia of explosives has been studied that relies on the chemiluminescent reaction of nitric oxide with oxygen atoms. This reaction emits a visible continuum peaking in the blue-green. The method is specific to explosives containing nitro, nitroso, or nitrate groups. Air containing heated explosives vapors (1250° K) produces the fragments NO, CO_2, and H_2O. When gas containing these chemical species is mixed with gas containing atomic oxygen, the reactions are:

$$O + NO_2 \qquad NO + O_2 \text{ (VERY FAST)}$$

$$O + NO \qquad NO_2 + \text{LIGHT}$$

NO_2 produced in the reaction can again react with atomic oxygen to cause a chain reaction. The detector is capable of detecting 0.1ppm of NO. Detection limits are fixed by the purity limitations of available oxygen.

Condensation Nuclei

The continuous reading condensation nuclei counter was developed about 1950 for the purpose of counting small particles (10^{-7}-10^{-5} radius) in the atmosphere. A gas sample in which the nuclei are to be counted is first humidified essentially to saturation and expanded adiabatically into an evacuated chamber. The resultant cooling supersaturates the gas with respect to water vapor and the water vapor then condenses on the nuclei present. The growth is such that a particle of 10^{-3} micron diameter will develop into a water droplet of 5-micron diameter in about 26m sec. Although the original nuclei are too small to scatter light, the large water droplets are capable of doing so. The light scattered to a photocell, in a dark field optical system, is directly proportional to the concentration of condensation nuclei originally present. The complete operation is completed at 5 cycle/sec in commercial instruments. Readout is in terms of nuclei per cm^3. With a minimum detectability at 10 particles per cm^3, it is possible to detect material at the 4 x 10^{-7}gm/cm^3 level for material of density one and particle size about 10^{-6} radius. The initial application of the condensation nuclei was for ammonia analysis. In this way ammonia has been detected at the 5ppm level using equipment developed commercially.

The DC Discharge

The DC Discharge Emission Detector is currently under development for explosive trace gas detection. The instrument is being developed around a small enclosed DC discharge plasma that serves as the spectral emission excitation source. The emission spectra for NO are generated as nitro bearing explosive vapors are fragmented in the plasma. The emission spectra consist of band spectra between 2200 and 2750 angstrons (see Table IV) which are detected with a 0.25-meter scanning Ebert spectrometer and associated electronics (Figure 5). The limit of detection of the present instrument to TNT

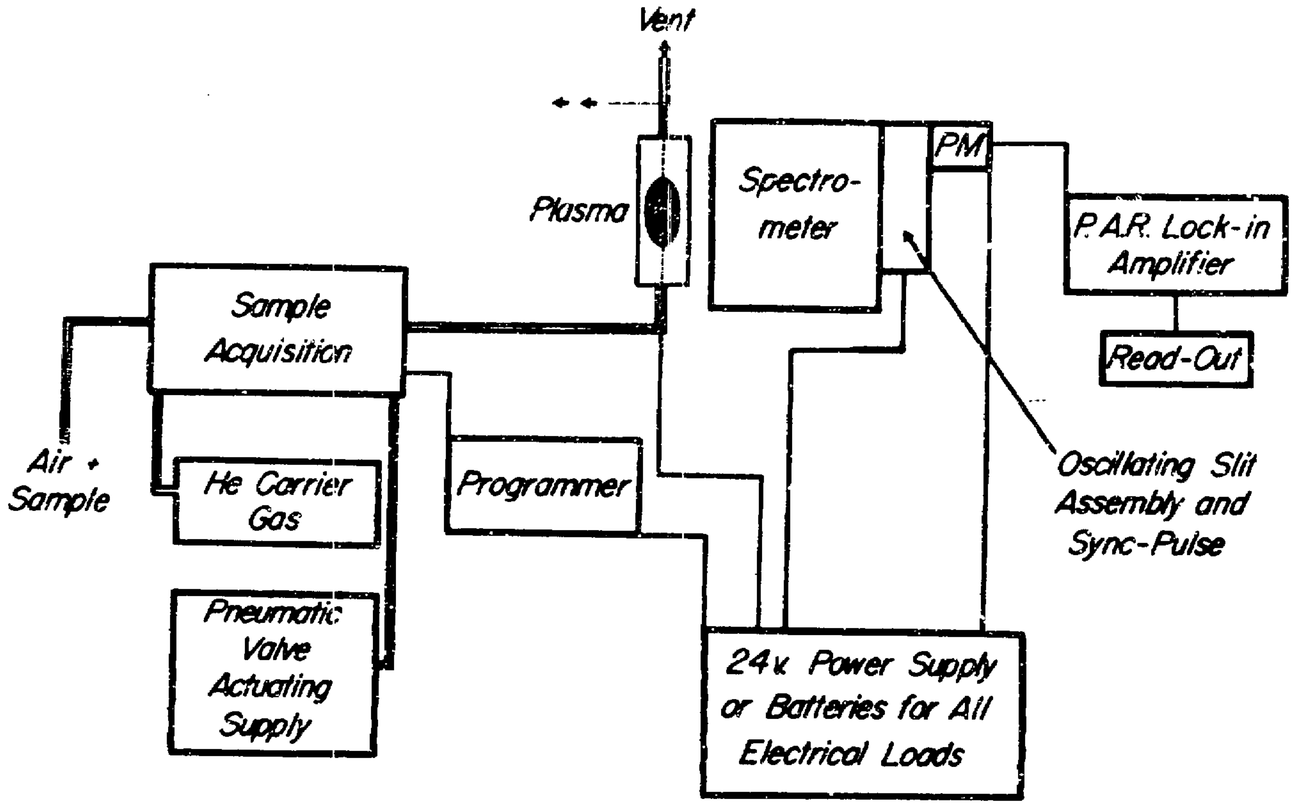


Figure 5. Detector System

vapors is seven parts in 10^{14} in a helium carrier gas. The instrument is the most sensitive detector of its type available, with the sensitivity being established in a laboratory without preconcentration. In order to employ the instrument as a field-operable explosive trace gas detector, a suitable sample acquisition system must be developed. A problem area is that explosive vapors adsorb strongly on the walls of much of the currently available tubing and housing materials. A preconcentration acquisition system is being developed which will utilize this adsorption property both to eliminate atmospheric NO interferences from the system and to preconcentrate the sample for the system. Delivery of the explosive sample to the detector is accomplished through thermal desorption of the adsorbed layer to introduce the sample into the helium carrier gas entering the detector (Figure 6). Other problems relating to unwanted adsorption of explosive vapors on cold surfaces internal to the detector are also under investigation.

TABLE IV

SPECTRAL DATA FOR SELECTED NO BANDS

λ	TRANSITION v' v''	INTENSITY
2269.4 2262.8	0.0	8
2370.2 2363.3	0.1	10
2478.7 2471.1	0.2	10
2595.7 2587.5	0.3	9
2722.2 2713.3	0.4	8

Summary

In summary, of the present developmental and potential techniques for the detection of effluvia emanating from explosives, only those techniques which appear to have the potential of detecting the equilibrium TNT vapor of one part in 10^{11} at 25° C should be considered as candidates for further development. At present, no detection system has the capability of performing this function in a real world environment. With the exception of the DC plasma discharge detector, achievable detection limits have been considerably less than required

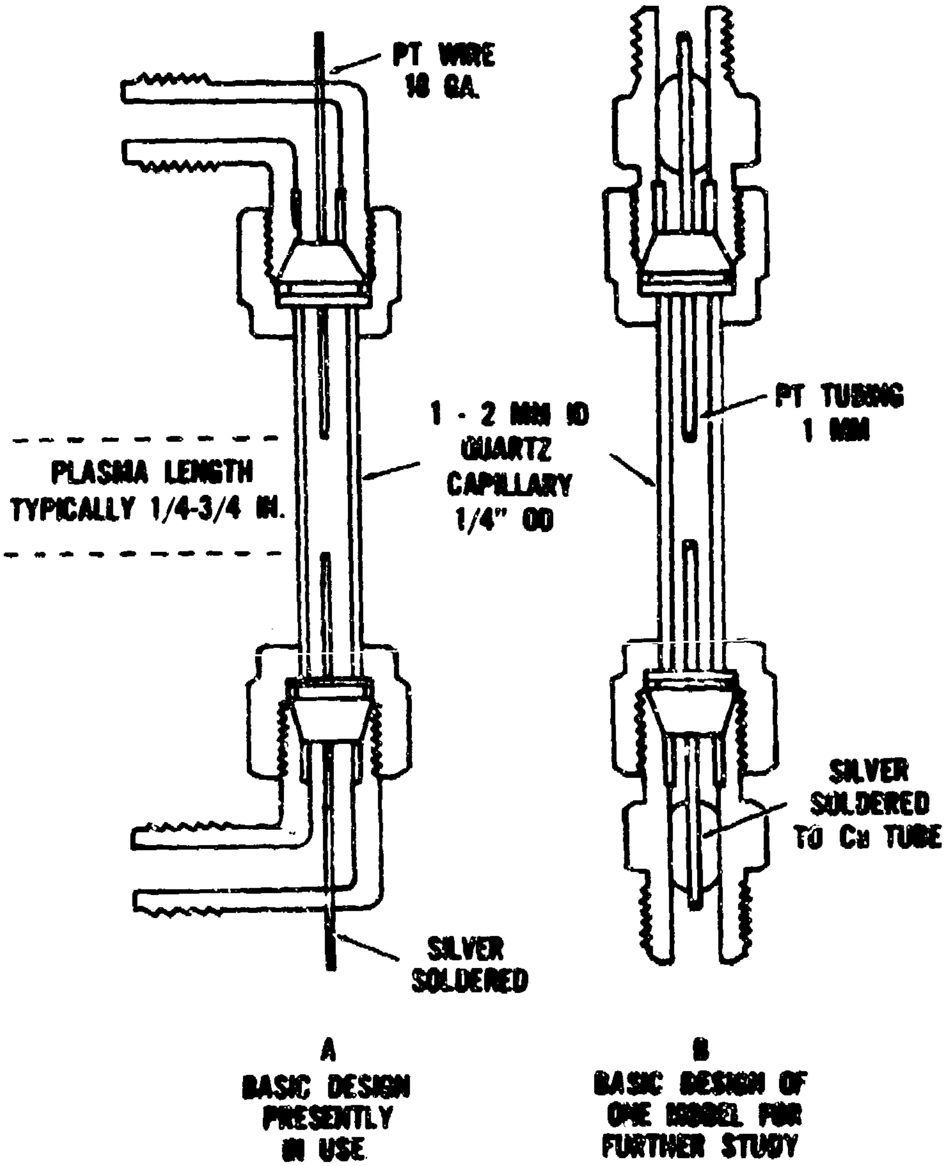


Figure 6. Designs of the Direct Current Discharge Detector-Discharge Chamber (Swagelock Fittings)

for TNT detection, even at equilibrium. It is estimated that the mass spectrometer can detect one part TNT vapor in 10^8; for the electron capture, one part in 10^9; for the biodetectors, one part in 10^{11} to one part in 10^{12}; for the plasma chromatograph (electron capture), one part in 10^{10}; and for the DC plasma discharge detector, seven parts in 10^{14}. Accurate estimates of sensitivity for TNT vapor have not been made for the condensation nuclei detector.

Technical Barriers

A technology barrier which is common to all trace gas detection techniques is the sample acquisition system. Explosive vapors adsorb strongly on the walls of many tubing and housing materials. A sample acquisition system which will utilize this adsorption property, eliminate atmospheric interferants, and preconcentrate the target vapors for delivery to the detector is a major requirement in all trace gas detection approaches.

ATOMIC AND MOLECULAR DETECTION TECHNIQUES

By: Dr. Timothy Small, Mine Detection Division, CM/CI Department, USAMERDC

I would like to begin by stating that my remarks will be directed more toward a discussion of phenomena rather than techniques. Some of you probably do not have an expertise in this area. In any event, for those who do, I ask for your patience since my presentation will deal with atomic and molecular phenomena in very elementary terms. I have no new detection techniques to discuss, nor will I be promoting any existing techniques; but I do want to give you a view of what is going on insofar as use of nuclear techniques in explosives detection is concerned.

Unfortunately, I was unable to attend all of yesterday's talks. I did get a feeling, though, that in the area of weapons detection substantial advances have been made. On the other hand, I think that there is no question that the detection of explosives has fallen far behind, primarily because this is a much more difficult problem. Consequently, this necessitates implementation of innovative ideas--"blue sky" projects that might not otherwise be tried if simple solutions were on the horizon.

The first question one has to ask concerning any problem of detection is: "What do you want to detect and what are its relevant characteristics?" The answer to this question in the case of explosives detection is not free from complexity. Different answers would be forthcoming from different sources. A chemist would probably talk about the kinetics of an explosive reaction. Others concerned with explosive's effects would talk about blast waves, and still others with deflagration/detonation discrimination. To me and to those people involved in this particular activity, an explosive is viewed as a physical object--a piece of matter. It is composed of atoms combined to form molecules. At the core of each atom is a nucleus. Certain properties within the nucleus are well-defined and well-known. The same is true of the electrical structure of the atom. The electron orbits of the atom are also well-known and, of course, characterize the various component elements. The same things can be said about the molecular structure of explosives. We have the basic knowledge needed to solve the problem of explosives detection. It is now only a matter of developing techniques--a means for inducing and detecting signatures.

Now, how do you use these characteristics? Obviously, a process is required which occurs over the realm of nuclear/atomic/molecular effects. This necessitates using techniques which have been developed over the last 20 years or so for similar basic studies in physics. The concept is to stimulate and observe a characteristic response which typifies the nuclear, atomic, or molecular properties of the microstructure of explosives. For example, in order to induce and detect nuclear processes you have to be able to inject a probing particle into the nucleus, and you must observe the response. The same is true for the atomic structure. A particle is injected which interacts with the electrons, and again a characteristic response is obtained. The same thing can be said of the molecular structure. In each case, a physical process must exist and be employed which can distinguish those unique physical characteristics which are common to explosives.

The atomic composition of explosives is characterized by the relative abundance of the various elements comprising the substance. This is of paramount importance to these studies. For example, almost all explosives contain nitrogen and carbon; most contain hydrogen and oxygen; and some contain a few other elements. The element that is most common to explosives and which appears in relatively large quantities is nitrogen. Most explosives (military and commercial) also contain a large percentage of carbon. So, here are two elements that one can seek to use as a general characteristic of explosives. The properties of these two elements can be used to generate signatures for explosives detection. So, we want to take advantage of these particular elemental constituents of explosives.

What I now want to do is talk about the processes which one can use. I will group the processes in two main categories, and I'll break these down as I go along. The first involves injecting a particle into a region of interest, a region in which it is desired to determine whether or not there is an explosive. There is a certain response which occurs, which is representative of the soil and includes a component due to a mine if it is present. It responds by emitting something which can be sensed by a detection device. In this way, information is collected and made available for further analysis and final display. Based on the information presented to him, a person can then make a decision as to whether or not there is, indeed, an explosive in that region.

The other category has to do with resonances of the nuclei in electromagnetic fields. These electromagnetic fields may be imposed externally, or they may exist as a consequence of the molecular structure. The technique used is to observe the precession of the nucleus, via the interaction of its magnetic moment with the electromagnetic field. The data obtained are such that the field which is producing this precession can be determined, or you can characterize the nature of the particle which is precessing in a known field. These are techniques which utilize nuclear-magnetic resonance and magnetic-quadrupole resonance phenomena. Such studies are currently under investigation in our program in the Mine Detection Division.

Now, I return to the first category, pertaining to particle interactions. This will be further broken down into two classes: (1) interaction of particles with the strong forces of the nucleus resulting in the emission of radiation; and (2) interaction of particles with the electromagnetic fields of the atom. The obvious particle to use for the latter purpose is the photon, the fundamental particle of the electromagnetic field. The requisite photon energies are in the X-ray/gamma ray region of several KeV up to several MeV. Photons with these energies can interact with matter in three basic ways. The first is Compton Scattering, in which one can, to a first order of approximation, treat the photon as scattering from free electrons. The photon effectively acts as a particle causing the electron to recoil while the photon is changed in energy and direction.

Another process, which results in total absorption of a photon, is the photoelectric effect. In this case, the photon actually interacts with the entire atom and affects its electron structure.

The third process has to do with pair production in which the kinetic energy of the photon is converted to mass. This is a novel concept to many people--the idea that you can actually convert kinetic energy to mass. In this instance, the photon interacts with the electromagnetic field of the nucleus, and by virtue of this interaction is able to convert its kinetic energy into an electron-positron pair. The positron will eventually slow down and recombine with an electron. When it does, there is formed what is called annihilation radiation. In order to conserve momentum and energy, the annihilation radiation is composed of two photons which have equal kinetic energy. Since recombination usually occurs near rest, the photon energies are equal to the rest mass energy of the electron (or equivalently the positron since they are both equal in mass).

These processes can be used in a variety of ways for explosive detection. For example, one of the techniques that we use in mine detection has to do with the back-scattering of lower energy X-ray/gamma ray radiation.

The competing Compton and photoelectric absorption processes determine the nature of the back-scatter. Compton scattering is required to reverse the photon direction. The probability of Compton scatter is dependent only on the number of scattering centers, to a first approximation, which in turn is proportional to the density. In the case of a buried mine, the density of the soil and mine are nearly equal; therefore, while the Compton effect will cause the injected photons to back-scatter and make detection possible, it alone will not provide a mine signature. The photoelectric effect can be used to provide the signature because its absorption cross-section is strongly influenced by the atomic number of the target atom. The average atomic number of explosives in a mine is approximately half that of soil with a resultant significant decrease in absorption probability. Thus, inclusion of a mine in the soil would increase the back-scatter signal above the ambient soil back-scatter alone.

One of the requirements for a detection system is that the injected radiation has to be able to get into the region of interest, and resultant radiation has to be able to get out and into the detection device. Acceptable penetration characteristics is one of the reasons energetic photons are good probe particles. Higher energy photons have sufficiently small absorption cross-sections to allow penetration to mine depths. But, in the case that I just mentioned, the absorption must not be so small that you cannot see an effect. So, there is a tradeoff.

Another phenomenon which is under investigation also involves photoelectric absorption, but in a different way. When an injected photon is absorbed, one of the bound electrons is ejected. This is an unstable condition and the excited atom is quickly reduced to its ground state by subsequent redistribution of the electrons. These transitions result in the liberation of "characteristic radiation", a photon radiation which is characteristic of the target atomic species. Since each element has its own unique characteristic radiation spectrum, this technique can be used (subject to radiation penetrability constraints) to determine the distribution of elements in a sample volume and hence identify the presence of those elements which are common to explosives or explosive devices.

You can probably think of several other ways of approaching the problem via photons, but I want to go on now to another process having to do with particulate matter. Charged particles could be used for probes, but the energies required to inject these through an overburden (in our case, in soils) are quite excessive. It is extremely difficult in the current state-of-the-art to deploy an accelerator in the field to provide requisite energies. Adequate accelerators are laboratory-type equipment, and will probably remain so for some time. So, we have confined ourselves to uncharged particles, of which neutrons are the most convenient to produce. In our case, we need to be able to penetrate through soils to the mine. In your case, a less restrictive requirement may exist. Nevertheless, neutrons have the additional feature that a radiation, which is characteristic of the element, is given off upon absorption of the neutron, by scattering of the neutron from the nucleus, or by many of the inelastic processes in which a neutron can interact with the nucleus. The probability of each process occurring is dependent upon the nuclear species and the neutron energy, and each process produces a different emission spectrum. Thus, nature has provided in neutron scattering/absorption a tantalizing technique for explosives detection, but has made it a technically difficult technique to implement.

Neutrons are categorized by their speed (or kinetic energy); the two primary categories are thermal neutrons and fast neutrons. Fast neutrons become thermalized by scattering as they penetrate matter. This moderation process is quite rapid if there are copious quantities of protons, the nuclei of hydrogen atoms, from which to scatter. The cross-section is quite large, and each scatter results in large kinetic energy transfers to the proton quickly decreasing the energy of the neutron to thermal levels. Thermal neutrons are eventually absorbed with a typical path link on the order of a centimeter. Some nuclei have a great affinity for thermal neutron absorption, while others have a very small cross-section. Conveniently, nitrogen has a relatively high thermal neutron absorption cross-section, thus facilitating explosive detection by this technique.

Fast neutrons have some good characteristics as probe particles in their own right. Inelastic cross-sections of carbon and nitrogen are sufficiently large and fast neutron source development is adequately advanced that considerable effort has been expended to implement fast neutron inelastic scattering techniques for mine detection. One of the major impediments is the massiveness of the radiation shielding required for isotropic sources for the purposes of protecting personnel and equipment and reducing background.

Using activation techniques for explosive detection in luggage has been investigated under the auspices of the Federal Aviation Administration. Basically, the concept is to inject fast neutrons into the luggage; one of the reactions with nitrogen (again used to characterize explosives) which will occur results in the formation of an isotope nitrogen-13; the isotope decays with a half-life of 10 minutes emitting a positron. As mentioned earlier, the ultimate destiny of most positrons is annihilation with an electron producing annihilation radiation; this radiation is detected and used as the signature of an explosive. Disadvantages arise due to the lack of specificity of this technique. Other isotopes with comparable half-lifes and emissions are formed by similar processes from elements which are not present in explosives. Also, nitrogen is present in some other items commonly found in luggage. Other difficulties also arise which affect the overall deployability even though they do not affect the ability of the technique to detect explosives.

I have described several of the techniques which are under consideration for explosive detection by nuclear techniques. Many are quite "blue sky" in nature but are still being considered because of the general inadequacy of the technologically simpler techniques. Hopefully, the problems can be solved so that an efficient, reliable explosive detection technique will soon be fielded to satisfy one of society's most urgent technological requirements.

HUMAN FACTORS ASPECTS

By: James Wallen, Jr., Mine Detection Division, CM/CI Department, USAMERDC

One of the most successful methods of locating mines and booby traps in Vietnam has been human sensing. According to recent statistics, 80 percent of the mines and booby traps there were detected by individuals without the aid of artificial sensing devices. Some of these individuals had operated for periods of up to 5 years in highly vulnerable positions, such as point man on long range patrols. In many instances, they displayed an uncanny ability for locating mines, booby traps, and ambushes.

About a year ago a pilot effort was initiated in the Mine Detection Division to determine whether sufficient statistical evidence was available to justify a thorough investigation of human sensing for mine and booby trap detection. A few remarkable individuals who had engaged in road clearing sweeps and patrol operations were questioned on how they and their fellow soldiers were able to detect buried and hidden offensive objects. In some cases they reported rather obvious visible evidences, such as disturbed earth or discarded fuse holders. These were used as alerting and guiding clues. In other cases, the individuals could not recall any specific factor which could be used as an identifying clue. Instead, the searcher had the "intuitive" feeling that things were not precisely as they should be, which in turn alerted him to conduct a more thorough search of a specific area.

Based on limited but impressive statistical records compiled from actual combat experiences, and also on the circumstantial evidence revealed in selected interviews with veterans, it was concluded that use of the human as a basic sensor of concealed objects deserved further investigation. A comprehensive two-phase program was then outlined, with phase one of the program beginning in February of this year. The objectives of the first phase were as follows:

1. To fully evaluate the available military statistics relating to mine, booby trap, and ambush detection; and to identify those individuals with proven records of superior performance in locating concealed targets.

2. To interview a substantial number of average and superior individuals in an effort to determine those personal characteristics which contribute to superior performance.

3. To determine the dominant sensory mechanisms contributing to concealed target detection.

4. To determine the feasibility of selecting and/or training individuals for effective detection of concealed objects.

Phase one is a cooperative effort between MERDC and the Human Resources Research Organization, and is concerned mainly with locating, interviewing, and testing personnel having extensive mine and booby trap detection experience in Vietnam. Locating suitable personnel is being accomplished in cooperation with CONARC installations within the United States. Thus far 45 subjects from six different installations have been identified, selected, and interviewed. All subjects are from infantry units. A set of test instruments has been developed on the basis of an intensive review of those cognitive and personality factors which could possibly affect detection performance in varying situations.

Interviewing and testing of the 45 subjects have been completed, but the data have not been fully analyzed. No firm conclusions can be presented at this time. However, certain trends appear to be developing. For example, during the interviews it was found that some individuals among the 45 subjects had, under similar circumstances, substantially better mine and booby trap detection records, even though the subjects had comparable training, education, and backgrounds. Another preliminary deduction is that the degree of personal motivation and the awareness of one's surroundings account for much of the variability between individuals. From comments made by the subjects, it seems that eyesight is the predominant sensory mechanism involved in detection. For example, the subjects rated color of the device, soil around the device, and camouflage and vegetation around the device as major factors affecting detection. As for the other sensory mechanisms used in detection, 12 subjects used hearing, 11 smell, and 42 reported "a special feeling." Comments were solicited from the subjects on "special feeling." The comments did not appear to link emotional changes to a given sensory input. Analysis of the data obtained from the 45 subjects should be completed in about 2 months. Conclusions relative to the objectives of phase one of the human sensor investigation will be drawn at that time and a report published.

I shall now turn to phase two of the program. This phase is primarily aimed at determining the feasibility of utilizing the human as a basic multimade sensor or transducer. This task is still in the formative stage, and experimental work is not expected to begin before early 1973. Use of the human as a sensor is based on the fact that when an individual is threatened by an external action, certain measurable physiological changes occur. The threat may be sensed by any one or combination of the five normal senses, or by extra sensory means, if man does, indeed, have such a sensing mechanism. For our purposes, a man will simply be treated as a transducer, producing measurable physiological changes when exposed to a concealed threat.

Therefore, we will not be concerned about whether the sensing mechanisms are attributable to man or whether they are considered ESP. Normal contact methods of measuring physiological changes can be employed.

The purpose in conducting experiments of this nature is to see if the sensing actions of man can be more accurately communicated through physiological changes rather than through conventional human means of communication, such as speech or action. Since man is inhibited to a large degree by the social order, he may intentionally or inadvertently mask the emotions which tend to degrade him in the eyes of his peers. Consequently, his normal communications are often distorted, either intentionally or inadvertently, in order to mask his true emotions. Conceivably, the physiological monitors could overcome inadvertent communication inhibition in the same way that polygraphs overcome intentional false communication.

There are two major technical barriers which must be addressed before a successful experimental program can be implemented. First, a human subject must be exposed to an actual threat and his physiological parameters measured, without the measurement affecting the sensory mechanisms. Secondly, complex physiological response patterns must be generated and analyzed to see if characteristic patterns result from specific threats.

Two solutions are being considered for the first problem. The first solution is miniaturized, unobstructive contacting sensors. These can be attached and utilized on a subject in real time. Data can then be telemetered to a recording and proces ing station. Another possible solution is to obtain video tape or motion picture film of a subject under actual field threat conditions. A short time later the recorded imagery can be used as a prompter to insure that the subject accurately relives the situation while under hypnosis. Physiological measurements would be made during the "hypnotic rerun."

The second method which I have just mentioned may be especially useful for PKPF applications. For example, in the case of the assassination attempt on Governor Wallace, the news media film of events leading to and including the shooting could be used to prompt the would-be assassin. If his cooperation could be obtained for hypnosis purposes, it would be possible to do a physiological rerun of the event, and a physiological pattern could then be developed for persons attempting assassination. Also, film of previous Wallace gatherings in Detroit and Wheaton, which the alleged assassin attended, are available, and they could be utilized to determine whether similar physiological responses were stimulated in the individual.

Let me return now to the second major technical barrier which I mentioned a few moments ago, that of characterizing the physiological response pattern. Consultation with psychologists and physiologists knowledgeable in this area indicates that only simple physiological patterns representing simple emotional and sensory experiences have been characterized at this time. Characterization of physiological patterns of particular interest to us may require several years of continuous effort and a significant advance in the state-of-the-art. Our present plans call for finalizing an experimental approach and conducting some exploratory investigations so that an assessment of the magnitude of the problem can be made in early 1973.

CANINE DETECTION

By: Henry Knauf, Mine Detection Division, CM/CI Department, USAMERDC

During the course of this symposium, papers have been presented dealing either directly with solutions to the problem of public figure protection, or indirectly as by-products of solutions to mine detection problems. Whether the contraband items are explosives, narcotics, or weapons, one central theme emerges, and that is, the search for contraband is conducted on personnel or in packages passing through a controlled access point.

The tragic events of Monday (the attempted assassination of Governor Wallace) re-emphasize the need for directing research efforts towards a solution to contraband detection. Of special need is a method for detecting handguns concealed on individuals located in crowds, especially those encountered at political rallies. How does one accomplish this screening procedure? Trained law enforcement personnel acting as body guards are alerted to individuals who act in a suspicious manner at these gatherings. Body guards have two functions: first, to shield the intended victim; and second, to apprehend the culprit. But, this is not an adequate nor a very pragmatic solution.

One asset that has not been fully explored is the extremely intelligent, highly trained, specialized dog. This animal, remarkable for its olfactory acuity, has been trained to perform various functions. The most common functions, indeed the most useful for law enforcement personnel, are patrol, sentry, or tracker duties. Among the more specialized functions performed by these dogs, the performance of which MERDC is presently investigating, are mine/booby trap detection and narcotic/explosives detection. MERDC is also negotiating the award of a contract to evaluate specific breeds of dogs which can be trained to search for weapons concealed on the person of individuals located in crowds. Because the weapons detection dog will be carried in the arms of its handler during the search, problems of transporting the dog in the crowd and transmitting the dog's alert to the handler must be solved. As a second approach, large dogs, such as the German Shepherd or Labrador Retriever, can be trained for this task, conducting the search in the guise of seeing-eye dogs.

Although, as mentioned earlier, the Mine Detection Division's raison d'etre is mine detection, I want to discuss only that aspect of the program which deals specifically with public figure protection. Under this program, MERDC has contracted with Southwest Research Institute, through the Land Warfare Laboratory, for delivery of three dogs already trained in detecting explosives and narcotics. Two of these dogs, a German Shepherd named "Apache" and a Golden Labrador Retriever named "Pearl," are scheduled for delivery in mid-June.

A third dog, a standard Poodle (either a male named "Stanley" or a female named "Linda") will be delivered to MERDC in mid-July. You will have the opportunity to witness these remarkable animals perform during the demonstrations planned for this afternoon. A black Labrador named "Doug" has been graciously loaned to us for this demonstration by Southwest Research. This dog served in Vietnam as a tracker and a narcotics detection dog. It has been trained on explosives for the past six days only. However, do not get the impression that any dog can be trained this rapidly. This dog underwent extensive training prior to its combat role, and had only to be introduced to the new odor which he was expected to detect.

I believe that the dog is presently the only pragmatic solution, not only to public figure protection, but also to many mine detection problems. However, I do not feel that a canine detection system is the ultimate solution.

MERDC is presently investigating other animals, such as the coatimundi, fox, and pig, as well as other breeds of dogs to determine their potential detection capability in both mine detection and public figure protection roles. The coatimundi showed some promise, but was dropped from the program because it was easily satiated and would not work unless it was hungry. In its native South America habitat, this animal is accustomed to fasting for long periods between feedings and searches for food only when it is faced with starvation. When hungry, the coatimundi works exceptionally well, but it cannot be conditioned to work solely for the praise reward ("good animal," or petting). The fox is presently being domesticated for explosives detection training. It will be evaluated to determine its potential for explosives detection.

The dog is highly motivated by praise reward. The "good dog" and the pats lavished on the dog by its handler achieve the result of having the dog work harder in its search for concealed contraband. In addition, a food reward is given the dog for each successful detection, thus stimulating the desired behavior. However, unless the dog is maintained at slightly less than its normal food intake, this type of reward is impractical.

To date, the most promising animal, aside from the dog, is the pig. Three problems are immediately encountered which limit the usefulness of this animal as a detection system in various environmental situations. These are: (1) the animal's rapid growth; (2) its social unacceptability; and (3) its unpredictable bowel movements.

A partial solution to the first problem is achieved by maintaining the pig on a high protein diet. This seems to retard its growth to some degree, but it is only temporary. However, training can be accomplished during the piglet stage. The animal is a successful detector system at an early age. In contrast, a dog must be about nine months old before any serious training can be started. A puppy is mainly interested in fun and frolic rather than work.

The piglet is an intelligent subject and quickly masters the search technique. The reward is usually corn, and this, of course, aids in maintaining its nutritional requirements. Also, the pig is not readily satiated, (perhaps, at one time this derogatory expression applied to a gluttonous individual), and will reliably and eagerly search for long periods of time. Praise, as a form of reward to motivate the pig, is useless. It is interested solely in food associated with a successful detection. Problems associated with social acceptance of the pig are not easily or readily solved. Civilians would not welcome a pig sniffing at their person or personal items; nor are they apt to quarter a pig as a pet. In fact, most county ordinances would forbid it.

Law enforcement and military agencies are not likely to accept any animals except the dog, and, of course, the preference in dogs is the German Shepherd. Discussions with individuals assigned to law enforcement tasks, such as narcotics detection, have been vocal in their disdain of dogs other than the German Shepherd, although the Labrador Retriever and Hound have been accepted to some extent for certain missions. Foreign governments use other breeds, such as the Alsatian, but the German Shepherd has long been considered the basic law enforcement and war dog. Mention of the Poodle as a possibility for bomb or narcotics detection invites comment such as: "What respect would a dock worker have for a law enforcement officer with a Poodle at his side? Go in there with a German Shepherd and you command respect."

The military has a very high regard for the German Shepherd. A study, funded by the Office of the Army Surgeon General and conducted by the University of Maryland, was made to determine the breed that best fit the requirement for a detector system. The Biosensor laboratory of the Walter Reed Army Institute of Research, OSG, has undertaken a program to genetically improve the German Shepherd for military related tasks. At this time, animals other than the dog do not meet programmed military requirements.

The third problem, the pig's unpredictable bowel habits, is not a detriment to its acceptance as a detector system. It is of little consequence where it relieves itself in the environment of mine/booby trap situations. Maintaining cleanliness when searching aircraft or buildings under a bomb alert could be achieved by using a diaper on the pig. Presently, no effort has been expended towards training the pig to regulate its bowel habits; however, this possibility has not been rejected. Successful and reliable contraband detection is the major problem, and to this end, the pig merits further consideration.

Examples of specific scenarios in which the pig could be used are covert screening of individuals and baggage search. Personnel screening could be accomplished by housing the pig in an enclosed area adjacent to a controlled access point. Individuals desiring admittance to an aircraft, for instance, would pass through a stream of air, such as that generated by a fan, which would be directed into the pig's enclosure. Contaminants associated with contraband items concealed on the individual passing through the air stream would also be carried to the pig. If the animal detects an odor associated with a contraband item, it could alert its handler by activating a switch. The suspect would then be diverted for a more thorough search.

The pig could also be used to search baggage consigned for shipment prior to loading on a commercial carrier, or it could be used to search packages in a post office. In this situation, the pig would be isolated away from any human contact other than its handler. Packages which cause the pig to alert would be set aside for later inspection by the proper authorities.

Preliminary experiments made to test the feasibility of meeting this need were quite successful and indicated that the pig excelled in comparison to the dog. Small quantities of explosive material, approximately the amount needed to fill a toothpaste cap, were concealed in various locations in a room. The pig readily found each item, pausing after each detection only to receive its reward. Indications are that it is not easily distracted, nor does it become bored with repetitious tasks as does the dog. Larger quantities of explosives will be used in later experiments to simulate actual bomb threats. Control items (salted packages) should be periodically inserted to check the reliability of the pig's performance and also to assure that it is properly motivated. It works only for food received for successful detections, and must be rewarded at random intervals. In the real world situation, the probability of daily or weekly shipments of contraband is low.

I would like to conclude by briefly mentioning some of the other areas which MERDC is investigating. First, however, let me say that it is not the Center's desire to replace the dog with a pig or any other animal. The Mine Detection Division is trying to provide solutions to problems associated with public figure protection as well as mine/booby trap detection, and a logical candidate for achieving both goals is biosensor detection. Areas of interest to MERDC are:

1. To comparatively evaluate various canine breeds and the genetically improved generations of selected breeds for mine detection.

2. To investigate canine physiological reactions to mines and booby traps.

3. To determine canine olfactory sensitivity to mines and booby traps.

4. To develop remote monitoring and control devices for covert canine detection via telemetry techniques.

5. To devise improved canine training and handling techniques.

6. To investigate the physiological and psychological responses of humans as applied to handler selection and training techniques.

7. To resolve the care, maintenance, and logistics techniques for the mine dog/handler team.

BOMB-DETECTING DOGS IN NEW YORK CITY

By: Dr. Michael Lauriente, Office of Systems Engineering, Department of Transportation

As an introduction, Figure 1 shows the first public announcement of bomb-sniffing dogs being used or tried at airports. With the lid off, interest in this type of activity increased considerably. The editorial paid tribute to the dog, but, of course, we know that behind this effort there were many people who deserved credit also. The Department of Transportation (DOT), once realizing the potential, became quite interested in bomb-sniffing dogs as one method of handling the insidious problem of sabotage at airports.

In the Washington, D.C., area, there is a project in progress under the Federal Aviation Administration (FAA). Dogs to be used at the Washington, D.C., airports are being trained under the British system--the one-man/one-dog system. Assigned to the Fairfax County, Virginia, Police Department, the dogs will be trained at Washington National Airport and Dulles Airport. By comparison, a different system of training was used in New York--commonly known as the food reinforcement concept. Training, in this instance, emphasized the seek-and-reward principle. The dogs received initial training at the University of Mississippi under Ray Phillips. They were trained to sit when explosives were detected and to recognize all known military and domestic explosives. No sentry training was attempted. These dogs were trained exclusively for sensing explosives.

From the University of Mississippi the dogs went to the Land Warfare Laboratory (LWL), Aberdeen Proving Grounds, for further training under Dr. Kraus. They were subsequently assigned to the New York Bomb Squad for field training under Lt. Ken O'Neil. After being informed of the availability of the dogs, I made informal approaches to the Army to see if they would be interested in feasibility tests at the New York airports. I also approached Mr. Lou Mayo, the program manager at LEAA. A meeting was arranged and held on July 9 to discuss the matter. Present were Mr. Mayo of LEAA, Mr. Wallace of the Office of the Mayor, Lt. O'Neil, head of the Bomb Squad, and Mr. Blue, representing the FAA Eastern Region in New York.

Broad guidelines were discussed, including inspection of luggage moving on conveyor systems and the testing of dogs in crowds to see how much distraction they could stand. We were particularly interested in seeing how fast 747 aircraft could be cleared, especially in the cargo area. We were also interested in seeing how well the dogs could detect explosives in sealed containers, such as closed garbage cans or interior seat pockets.

On the basis of the agreements reached by the New York Bomb Squad, the FAA, and LEAA, the program was initiated. At that time,

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BLACKMAIL BY BOMB

Something new and deadly in the field of air piracy was unveiled Tuesday.

An as yet uncaught two-legged rat planted a bomb in the cockpit of a Trans World Airlines jetliner at Kennedy Airport, then telephoned a demand for $2 million as the price of not blowing up this ship and three others at six-hour intervals.

Hero dog Brandy

At Las Vegas yesterday, a TWA jetliner was badly damaged by an explosion—perhaps to show that this blackmailer by bomb means business.

A round of applause is due the city police bomb squad's dog Brandy, trained to smell out explosives, who duly spotted this bomb in time for it to be defused by Detective William Schmitt. May such dogs' tribe increase, but fast.

And may all the world's governments, lawmakers, airlines, and other interested elements redouble their efforts to combat and eventually conquer this criminal menace of air piracy. We simply cannot tolerate it or condone it in any way.

Figure 1. Editorial on New York Bomb Squad Bomb-Sniffing Dog Which Appeared in the New York Daily News

the dogs were still in the preliminary phases of training by the New York Police, a training which emphasized office searches. We were seeking an answer to the question of how well dogs could adapt to another type of search; that is, the search of confined and closed quarters of an aircraft. I am referring, specifically, to a schedule laid out by the FAA which lists the various areas of concern. These are the cockpit, galley, cloakroom, lavatory, lounges, cargo compartment, baggage makeup rooms, conveyor belts, and containers. We were also concerned with reactions in the various environments (terminal areas, confined areas, and isolated areas), and to odors and airport distractions. The different types of exercises to be conducted were carefully planned for these purposes.

Figure 2 shows the sensitivities for detecting trace odors by a moth, dog, and human, respectively. I understand that human sensitivity can exceed that of the dog for certain molecules; but, in the greatest part, it is the order shown in the Figure. I think, in the last analysis, that the dog is better than man in this regard.

I would like to read at this time excerpts from the records that were made by the FAA in their field reports on dogs. In the first exercise it is reported that the dogs were handled separately, making test runs at each location and sniffing out previously placed specimens of small amounts of TNT. I read from the FAA record:

"In the aircraft, the galley space, first-class and coach areas were utilized. The specimens were located in varying lengths of time, from a high of 3 minutes to a low of 25 seconds, depending on the distance from the target the search commenced. The specimens were located at heights from ground level to about 2 feet high."

Now, I do recall that in these first exercises, the dogs had a great deal of difficulty going into the confined areas of the seats and backing out. Apparently, it was very confusing for the dogs. Also, the dogs had great difficulty in the beginning in searching for items placed above their heads. In previous training they were taught only to search at head level and below. These problems were subsequently resolved by further training. I read again from the FAA record:

"Exercise No. 3: As in past exercises, the dogs continued to be handled separately and each located a tough specimen in all cases. Considerable improvement noted in the dogs adapting to and indicating familiarity with aircraft and the various seating arrangements. To this end, a major change in the method of search was instituted. Since the dogs experienced difficulty in turning around in the narrower coach seating configuration, and have difficulty in backing out of the rows, they were allowed to adapt to their own search patterns. One comfortable to them. They were visibly more at ease and the quality of search notably improved. They were suc-

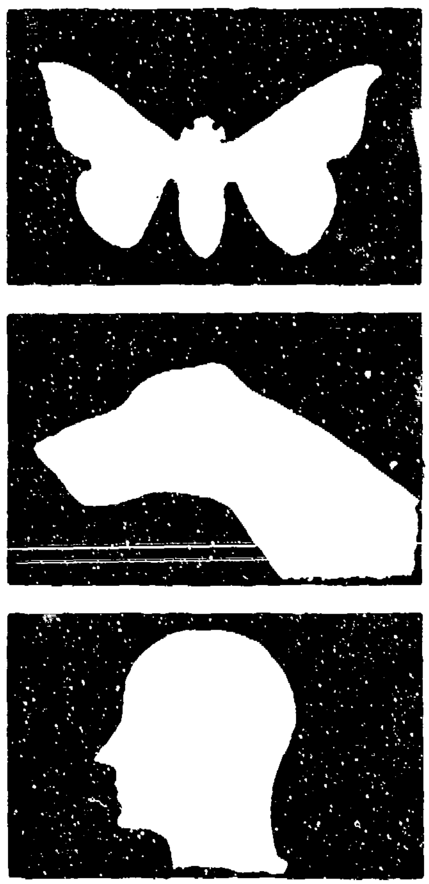

Figure 2. Approximate Sensitivities for Odors in Air

cessful in locating target specimens placed on the tops of seat backs as well as in cloakrooms and hidden galley areas. The dogs are not experiencing any difficulty with the various compartments of the numerous aircraft models encountered to date. Exposure for the first time to the conveyor belt systems and baggage makeup rooms was, in general, satisfactory. Further exposure, familiarization and evaluation is to continue in this area."

I might add that being able to detect explosives in moving bags is one area that we have not been able to duplicate to date with any instrument. Only if the bag is squeezed and the bomb sniffing instrument is close by, will an instrument work. Watching these dogs detect a moving bag was impressive. Again, from the record:

"Exercise No. 4: In this exercise a bomb threat situation was created by placing a test specimen in a hangar of a 707 aircraft, under repair, with crews working about for approximately 45 minutes before arrival of the dogs. The only information given each dog handler was: A bomb is on the aircraft ready to go off in 15 minutes; find it. The specimen was located within 3 minutes by each dog, with Sally the quicker. When the specimen was moved to another compartment, it was located almost immediately by Sally and within 2 minutes by Brandy." (I neglected to mention that "Sally" is the Labrador and "Brandy" is the German Shepherd.) I now read from the record of 29 September:

"On this day there were approximately 28 searches. As is customary they made individual searches. Their first test took place in the tourist section which, in this instance, was very untidy with food particles about the seats and on the floor."

I recall this one. There were juicy tidbits of shrimp, and being a dog owner myself, I know this is a very delectable item. In spite of this, they ignored it. Continuing with the record:

"In spite of the food laying on the floor, the dogs located the specimen within 2-1/2 to 3 minutes. For the following two searches, the specimen was placed in an enclosed compartment in the galley in the aisle. The specimen in the galley, although hidden well, provided no difficulty for the dogs. From the aircraft we moved into a storeroom which comprised an area of at least 60 x 60 feet. Here the dogs were given a rather difficult assignment, with three specimens being placed about the shelves and within boxes. With many of the employees of TWA looking on, the dogs averaged about 30 seconds in finding each of the specimens." I now read from the record of 1 October:

"During this plane search it was noted that the petting of the dog by a hostess distracted him from the search. He was not bothered by the several passengers who remained aboard eating their lunch. The final session was spent back in the baggage section where the dog was placed on a tough schedule with 17 specimens placed in difficult places, including the inside of a closed garbage can, on baggage transport wagons, wall locations a few feet above the ground, inside drawers, and in desks. The dogs performed all these searches in record time." From the record of 4 October:

"Nineteen searches: Moving on to the baggage makeup area, 10 separate plants were made; two were in containers, one high and one low, and each was successfully located. The dog then worked on the moving baggage belt for four times. The dog missed one of the passing bags. This miss was attributed to the bag being placed too far from the dog's scent range. Another plant placed between a row of stacked boxes was detected in 2 minutes. Working in an office approximately 12 x 12, the plant was detected in 10 seconds. The plant in the coat pocket was missed completely by the dog. The last plant behind a blackboard in a dispatch office was detected in 10 seconds."

I think that, in general, when the search is made in a confined area, such as an office or storage room (which is the type of environment in which the dog was trained initially), their performance is slightly better. From the record of 5 October:

"Cargo personnel advised the handlers of a shipment containing detonating caps and asked if the dogs could find some. The general area containing the caps was pointed out in order to save time. Each dog was sent out to search, and both were successful in locating the caps within 1 minute. Four searches were made in the baggage area and on the baggage conveyor belt. Each search was successfully completed in from 15 seconds to 1 minute." From the record of 6 October: "Arriving at TWA's terminal, a new approach was made in detection aboard a 707. Three plants were put aboard the aircraft and each dog was permitted to work at his own pace with little direction from the handlers. Sally had the first run and detected all three plants, one right after the other, in 2-1/2 minutes. Brandy was equally successful in her search, finding three plants in three minutes."

That essentially covers the routine types of searches that were tried on the dogs. Now, I also posed a problem to the Bomb Squad and the FAA. Since the dogs are normally in the Manhattan area of New York, what would be the dogs' reaction if we had to use a helicopter airlift? I had a chance to ride in a Coast Guard helicopter, and I think if I were a dog I'd be affected by all the noise. I have a log of the exercise. The drill was planned to proceed as follows:

1. This office, simulating a bomb scare aboard an aircraft, will alert the Bomb Squad and request the use of dogs for the search.

2. Depending upon the availability of the dogs, the U.S. Coast Guard will be called immediately and be requested to dispatch

a helicopter to the Wall Street Heliport for pickup and transportation of the dogs and handlers to the General Aviation Building at Kennedy International Airport (PA Police Building).

3. NYCPD Bomb Squad (kept on telephone hold - item #1 above) will be advised of the availability of the helicopter.

> NOTE: The Coast Guard and the Bomb Squad were aware that the drill would take place on 1 December 1971, between 0900 and 1200 hours (time was not specified). Both agencies agreed to participate, barring any real emergency operation that they might be involved in at the time of our call to them.

4. The Bomb Squad will dispatch two vehicles simultaneously, one carrying dogs to the heliport, and the other going directly to Kennedy International Airport. The purpose is to establish time differential, air as opposed to ground.

5. A station wagon from this office will be standing by at GAT awaiting the arrival of the Coast Guard helicopter and ready to transport the dogs to the aircraft. Time of landing will be logged and compared to time of arrival at GAT of the second vehicle (ground transportation) which was dispatched by the Bomb Squad in the city.

6. Prior to the arrival of the dogs at Kennedy International Airport, an aircraft will be planted with a simulated explosive by this office. The location of the plant aboard the aircraft will be known only to the person making the plant.

7. Upon arrival of the dogs, the person making the plant will leave the aircraft, allowing the dogs, handlers, and observers to work the aircraft without benefit of a clue as to the area of the plant.

8. The dogs and handlers will search the aircraft (log time aircraft entered and time hit made), with the handlers determining when the dogs make the hit. Handlers will have to make physical retrieval of the plant to prove a good hit.

At 1010 hours, on 1 December 1971, the drill was put into operation and proceeded as planned above. An exception to the plan was made in step #8. It was decided to allow the dogs to work on separate searches, the exception being that the plant was left in place after the first search, thereby allowing the second dog an equal opportunity to make a hit in its search. Time log was as follows:

1 December 1971

1010	Call to Regional Office requesting dogs - "Aircraft Bomb Scare at American Airlines Hangar"
1011	Call to NYCPD Bomb Squad (alert)
1012	U.S. Coast Guard (alert) respond to Wall Street
1016	NYCPD Bomb Squad left office (2 vehicles)
1023	Bomb Squad arrival at Heliport
1044	Bomb Squad arrival at GAT (second vehicle)
1049	U.S. Coast Guard arrival at Heliport
1052	U.S. Coast Guard departure from Heliport
1101	U.S. Coast Guard arrival at GAT
1103	Dogs' arrival at aircraft
1104	Brandy entered aircraft
1110	Brandy makes hit after two false hits
1111	Sally entered aircraft
1113	Sally makes hit
1130	Operation secured

Comments and Observations

From the time of the initial call to the Coast Guard and their arrival at Kennedy International Airport, there was a total time lapse of 49 minutes. This can be compared to a 32 minute total response time by the second New York City Police vehicle. The car responding to the New York Heliport had a 26 minute wait for the Coast Guard helicopter. On the surface, this seems to be an extraordinary time delay, but after all aspects are analyzed, it is probably a realistic time factor. In this case, the helicopter responded from a cold start, which required warm-up, instrument check, clearance, etc. This expanded the time. This, of course, could happen on any given call, otherwise we may have to wait for a helicopter on patrol in the lower region of New Jersey.

We think it advisable to have a standard operating procedure whereby a response by the Bomb Squad will be made by motor vehicle.

We feel that 99 percent of the time they will be able to reach the airport in about 30 minutes. For the other 1 percent, it is suggested that we keep the Coast Guard as part of our emergency plan. They could become an important factor when road conditions are such that it would take hours to reach the airport by car.

The dogs themselves appeared frightened of the craft at boarding time. They barked and snapped at the rotors; but once inside, they calmed down through the reassurance of their handlers. There was no problem deplaning and no apparent physical problems for the dogs as a result of their flight. Furthermore, the concensus of the handlers and observer opinion was that the air trip had no adverse effect on their ability to perform their prime function.

Following the dramatic episode at Las Vegas where an explosion occurred due to a concealed explosive, I again approached the FAA and asked if they would get together with the Bomb Squad to run an exercise with concealed explosives. They did run this exercise and the report was that it was found within seconds. The explosive in this case was the military plastic type. Apparently, the military plastic explosive is a little easier to find than TNT. It does give off an odor which, I am told, even human beings can detect.

The general conclusion reached by the FAA was that these dogs do have a place at the airport for emergency procedures of this kind. They do not seem to be influenced by common odors found at airports. These do not seem to disturb them. The trainer has often been asked: What is it that these dogs actually smell? Is it possible to camouflage the odor of the explosives? We have tried to conceal the odor of the explosives with foods that are very appetizing to the animal. The animal, when alert, seems to filter out the background. Admittedly, there have been times when the dogs have appeared on the scent and still have not given their best performance. Like human beings they have their days. During these tests we found that when the dogs worked as a team, if one dog had an off-day, the other would cover up for him. We can state a general rule: If it is really important, make sure that two dogs are present.

Until machines catch up, dogs are still the best explosives detectors available.

JOINT-SERVICES INTERIOR INTRUSION DETECTION SYSTEM--ARMS ROOM PROGRAM

By: Benjamin Barker, Intrusion Detection Division, CM/CI Department, USAMERDC

This presentation will cover a description of the Joint-Services Interior Intrusion Detection System (J-SIIDS) equipment and a short explanation of the J-SIIDS selection procedure. At the outset, it should be emphasized that most of the J-SIIDS components will be similar to those found in commercial intrusion detection equipment, but redesigned to ensure greater individual unit reliability. The aim, in this regard, is to reduce the false alarm rates and to enhance system compatibility. The J-SIIDS Program is primarily concerned with theft of weapons, munitions, and other controlled material from military arms rooms. However, there are many other J-SIIDS applications, both military and civilian.

There are over 10,000 arms rooms within the Department of Defense. This figure covers the active military services, reserve components, and the National Guard, with the Army having the greatest number. An examination of representative arms rooms discloses that they vary in size from small rooms in company areas to large warehouses and in use frequency from all day/every day to less than once a month. Finally, arms room construction ranges from plasterboard to reinforced concrete. These rooms are all vulnerable to attacks. In fact, there has been a marked increase in the number of robberies in which armed guards have been relieved of their weapons.

There are many different ways to break into an arms room. Attacking the locks or metal screens is one way. Forcible entry through walls, floors, or ceilings is another. To determine the relative ease of penetration through typical arms room walls, the National Bureau of Standards conducted tests to determine the time required to break through a number of typical construction materials using tools considered to be readily available. Penetration was considered successful when an opening of at least 96 inches square was made in the wall. Figures 1 through 5 illustrate some of the barrier materials tested, and the penetration results.

The first barrier consisted of 2 x 4 studs covered with plasterboard on each side (Figure 1). Without any tools being used, an opening was made in the wall in 3-1/2 seconds. The second barrier (Figure 2) was a 5-inch thick reinforced concrete wall. The 1/2-inch reinforcing rods were on 12-inch centers, vertically and horizontally. In this case, a 10-pound sledge hammer was used and an opening was made after 55 seconds. Against an 8-inch mortar-filled concrete block wall (Figure 3), the 10-pound sledge hammer made an opening in 45 seconds (Figure 4). The last penetration test was made on a wire-reinforced glass windowpane with a metal window frame (Figure 5). Here, a 2-pound hammer was used, and in 50 seconds the glass was

Figure 1. Double Plasterboard Barrier Easily Being Broken

Figure 2. Opening Made in 5-Inch-Thick Reinforced Concrete Wall by 10-Pound Sledge Hammer

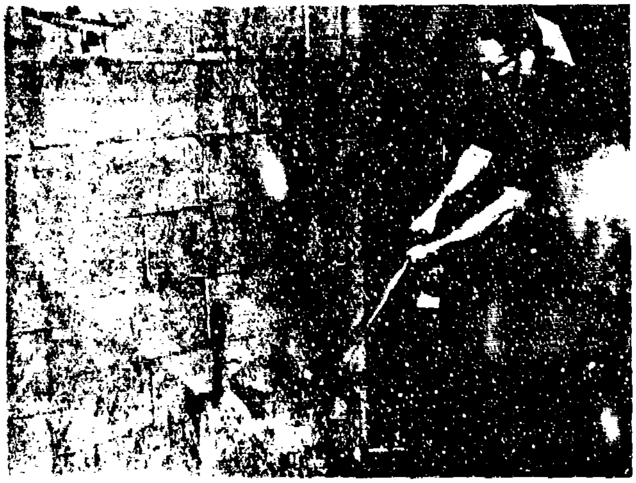

Figure 3. Application of 10-Pound Sledge Hammer on 8-Inch Mortar-Filled Concrete Block Wall

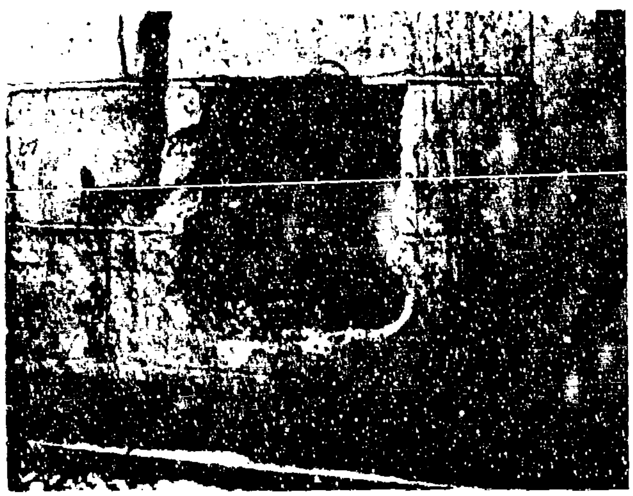

Figure 4. Penetration of 8-Inch Mortar-Filled Concrete Block Wall by 10-Pound Sledge Hammer

sufficiently cleared from the frame to allow someone to crawl through.

An analysis of actual breakins revealed that despite the varied designs of construction, materials used, locking hardware, and environments, all of the installations possessed a significant number of common characteristics. These were:

1. The facility was either in a quiet area or in an area where there was very little activity during lengthy periods of time.

2. Many individuals had access to the facility or were in a position to observe its layout.

3. Visibility from the exterior to the interior of the building was very poor, and in many cases not possible at all.

4. Numerous points existed where surreptitious access was possible; or places existed where a person could comfortably secrete himself during the time the facility was open and in operation, and who then could remove weapons without being detected.

5. Buildings were equipped with exits that provided for rapid egress.

6. It was easy to leave the general area of the facility and disappear in a network of escape roads unimpeded.

The concern about loss of weapons and the increasing incidence of penetration of sensitive areas led to the creation of the Physical Security Review Board at DoD, and in December 1970 the Secretary of Defense chartered the Defense Special Projects Group (DSPG) with the following task: "Direct or undertake in coordination with the military departments an RDT&E Program to provide effective physical security of arms rooms, installations, and bases." The objective of the program was to provide the Services with standardized intrusion detection equipment in the shortest time possible. This led to the procurement and evaluation by the U.S. Army Mobility Equipment Research and Development Center of a number of commercial devices. Testing revealed wide variations in equipment capability and provided the data base for specifications which have been written and reviewed by the Services. Contracts have now been awarded for prototype quantities. The successful test of these prototype units will lead to production contracts. The central procurement for all DoD is the responsibility of Army Materiel Command (AMC). The schedules for availability of the devices will be discussed later in this briefing.

Before describing the individual J-SIIDS devices, the system concepts and options will be discussed (Figure 6). The overall system is composed of a number of sensors, a control unit, a local audible alarm, and a remote monitor unit. This will probably be the basic

Figure 5. Penetration of Wire-Reinforced Glass by 2-Pound Hammer

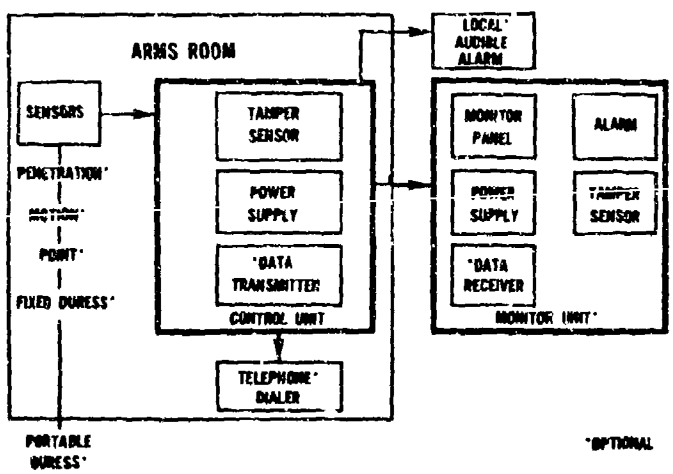

Figure 6. Joint-Service Interior Intrusion Detection System (J-SIIDS)

system for most applications. If it is not possible to use a remote monitor, then a telephone dialer could be substituted. The difference between the telephone dialer and the monitor unit will be discussed later in the briefing. When the system is in a secure status and any one of the sensors detects an intruder, the system automatically changes to an alarm status. The detection signal goes out from the sensor to the control unit which actuates a local audible alarm and simultaneously transmits an alarm signal to the monitor unit located at a charge-of-quarters desk, a base military police office, or any other desired location.

The major subsystems of J-SIIDS are: sensors, control unit, telephone dialer, local audible alarm, and data transmission system. The data transmission system is a hard-wire system capable of operating over ten miles of an unconditioned single-pair transmission line or over commercial grade telephone transmission paths. The Type 1 system utilizes a pseudo-randomly-coded message to provide transmission path security.

The sensors are categorized as follows: penetration sensors, motion sensors, point sensors, and duress sensors. Penetration sensors are those devices used to detect penetration through walls and doorways into the protected space of the arms room. Motion sensors detect the motion of an intruder within the confines of the arms room, while the point sensors detect the actual or attempted removal of a weapon from the arms rack. The duress sensors, of which there are two, are used by personnel to ca l for help at the press of a button.

The types of penetration sensors available are as follows:

1. Balanced Magnetic Switch
2. Capacitance Proximity Sensor
3. Grid Wire Sensor Kit
4. Vibration Sensor
5. Passive Ultrasonic Sensor

The Balanced Magnetic Switch (Figure 7) is a magnetically operated switch used to detect the opening of a secured door or window. The switch assembly mounts on the door or window frame and the balancing magnet on the door or window. When the door or window is closed, the field from the magnet interacts with a second field inside the switch housing to balance the new field and allow the switch to close. When the door is opened or moved a distance greater than one inch, the magnet is moved away from the switch. The field inside the switch forces the switch to open and an intrusion is signalled. When the switch is closed, any change in the external field, either by the addition of an illicit magnet to the outside of the switch case or by the insertion of a shield between the switch assembly and the balancing magnet, will disturb the balance and cause the switch to open and to initiate an alarm. The balanced magnetic switches include a tamper feature under the cover of the switch assembly to guard against attempts to disable the switch.

The Capacitance Proximity Sensor (Figure 8) is used to detect penetration through windows and ventilators. It consists of an electronics unit and one or more insulated metal grills. The grills are mounted across the opening that is to be protected. When the opening is disturbed (e.g., when a hand or tool is brought near the grill), the capacitance between the assembly and the ground is changed and the disturbance is detected. The range of sensitivity is approximately one inch for a human target. The Capacitance Proximity Sensor can also be used on a metal cabinet or desk if the item is placed on insulated blocks about one inch high.

The Grid Wire Sensor (Figure 9) detects forced entry through walls, floors, ceilings, doors, and other barriers by the break-wire method. An electrical wire is stapled in a closely spaced grid pattern over the surface to be protected. Any penetration larger than a 4-inch square will break the wire and cause an alarm. Finished paneling is installed over the grid to protect the wire from day-to-day abuse and to hide the exact location of the wire strands. For those cases where the installation has to be against a plaster or wire cage wall, a plywood foundation board can be fitted to the surface to be protected, and the wire stapled to the plywood.

The Vibration Sensor (Figure 10) is a disturbance sensor used to detect forcible entry through metal barriers placed over windows and ventilators. It consists of one or more sensor units and an electronics unit. It senses any vibrations of the metal barrier and generates an alarm signal when the disturbance continues for a time.

The Passive Ultrasonic Sensor (Figure 11) is an ultrasonic receiver used to detect the high frequency sounds generated by forced entry through metal and masonry walls and doors. It is also used on metal mesh, wire, barred or shuttered windows, and ventilation openings when they are properly sealed against outside sounds. The sensor consists of one or more separate microphone boxes, all connected in parallel to a single electronics unit. It listens for high frequency sounds, such as those emanating from saws, hammers or torches used in a break-in, and alarms when the sound persists for a short period of time. The coverage is an area approximately 12 feet wide by 24 feet long in front of each microphone. A maximum of 20 microphones can be connected to an electronics unit. There is no commercial equivalent of this sensor.

The Motion Sensor (Figure 12) is an ultrasonic doppler or frequency shift sensor used to detect the motion of an intruder inside the protected space. It consists of one or more separate ultrasonic transmitter/receiver boxes, all connected to a single electronics

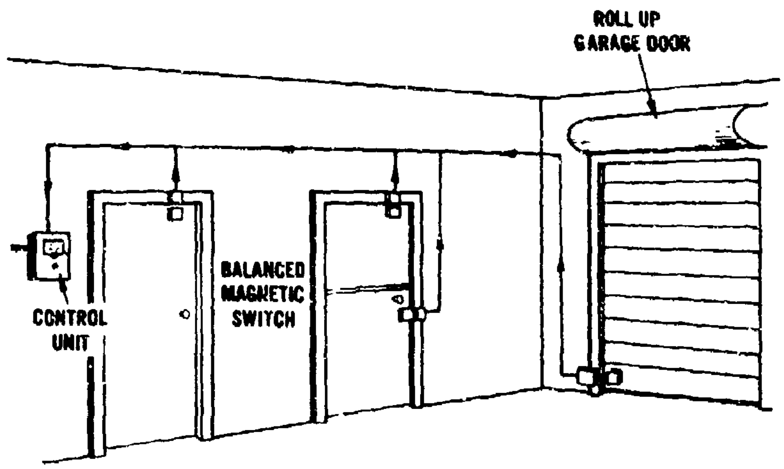

Figure 7. Balanced Magnetic Switches

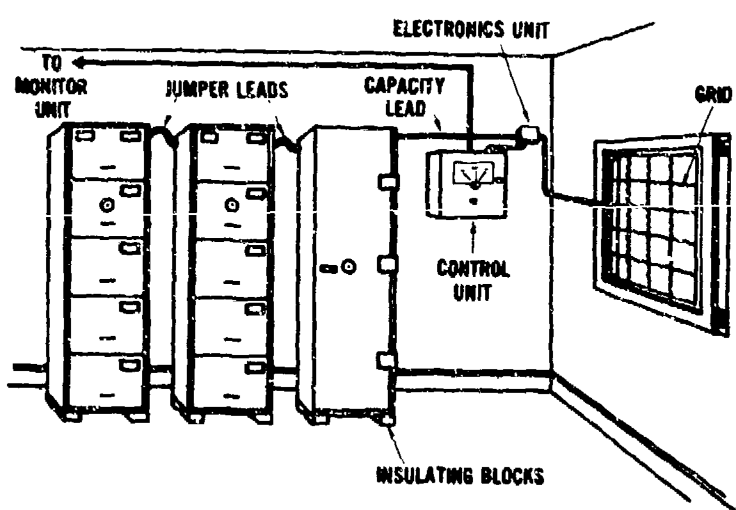

Figure 8. Capacitance Proximity Sensor

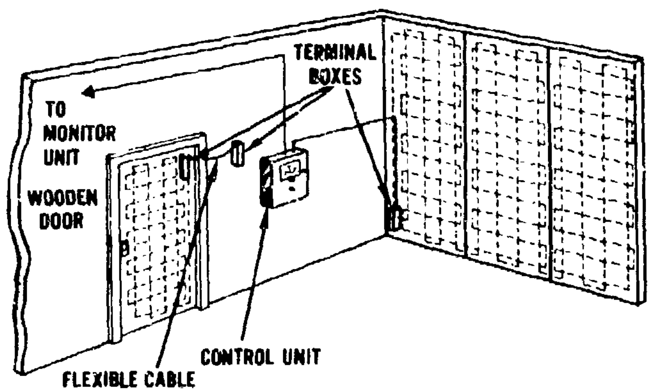

Figure 9. Grid Wire Sensor--Solid Wall, Floor, Ceiling Sensors

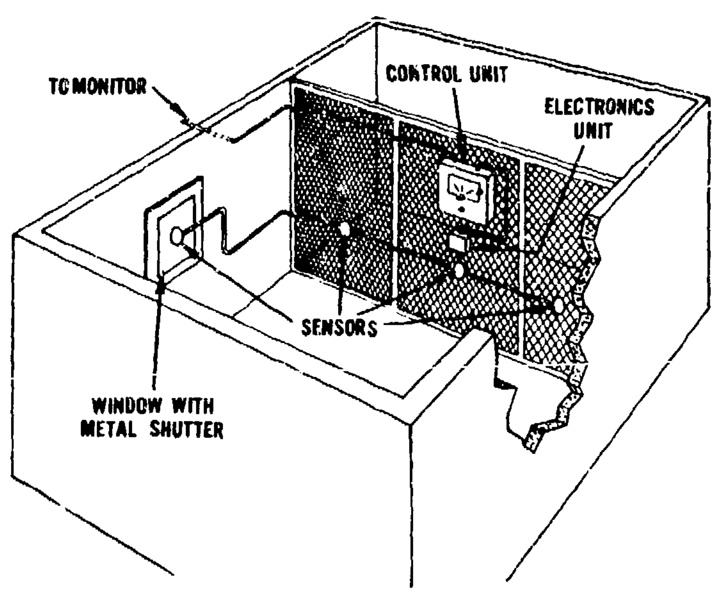

Figure 10. Vibration Sensor

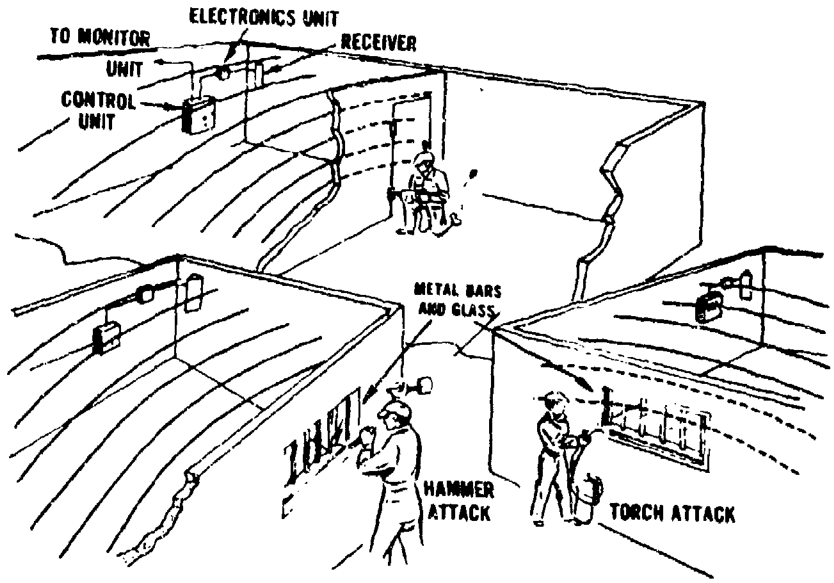

Figure 11. Passive Ultrasonic Sensor

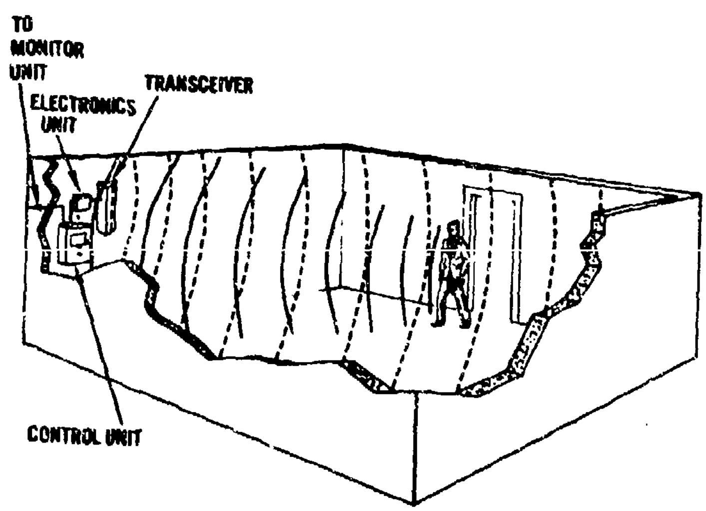

Figure 12. Ultrasonic Motion Sensor

unit. The transmitter fills the protected space with a steady tone well above the audible range. The receiver receives the signal reflected from the surroundings in the protected space. The electronics unit compares the received signals with the transmitted signals and initiates an alarm when the frequencies differ by a sufficient amount over a short period of time. When the surroundings are stationary, the frequencies are the same and there is no alarm. When an intruder moves in the room, the reflected signal is shifted in frequency and the intruder is detected. Special circuits in the electronics unit reduce the probability of a false alarm from moving air, vibrating walls and doors, or blowing curtains. The coverage of each transceiver is an area approximately 20 feet wide by 30 feet long in front of the transceiver box. Up to 20 transceivers can be connected to a single electronics unit.

There are two sensors in the Point Sensor Category: The Magnetic Weapons Sensor and the Capacitance Proximity Sensor. The Magnetic Weapons Sensor (Figure 13) is a wire loop assembly used to detect the disturbance of the earth's magnetic field caused by the removal of a weapon from the weapons rack. It consists of an electronics assembly and a wire loop positioned on the rack behind the rows of weapons. When a weapon is removed, the change of the magnetic field generates a voltage in the loop which is sensed, and an alarm is initiated. A single magnetic weapons sensor can be used to protect from one to 30 standard M-16 arms racks. There is no commercial equivalent of this sensor. The Capacitance Proximity Sensor can also be used as a point sensor in those cases where the weapons are stored in safes or metal cabinets. These containers are insulated from ground. The Capacitance Proximity Sensor will provide an alarm should an intruder touch the metal container.

The next group of devices is the Duress Sensors, used in calling for assistance. The Fixed Duress Sensor (Figure 14) is a manually operated switch located at a position within the arms room convenient to the armorer. One or more switches can be installed for operation by hand or foot. The Portable Duress Sensor (Figure 15) is about the size of a pack of cigarettes. It is a UHF transmitter carried by the guard, and has a separately enclosed receiver located near the control unit. The alarm signal, which can be initiated at any time by either Duress Sensor, is routed through the control unit to the monitor unit, or initiates an emergency message by the telephone dialer. The local audible alarm does not sound when the Duress Sensor is activated. Thus, the potential intruder has no idea that an alarm is being sounded. This decreases the chance of retaliation on the person that initiated the alarm.

There are several items of support equipment for the system. The first is the control unit (Figure 16). This is the terminal box for all the sensors and all the notification devices. It receives alarm and tamper signals from the sensors and passes appropriate

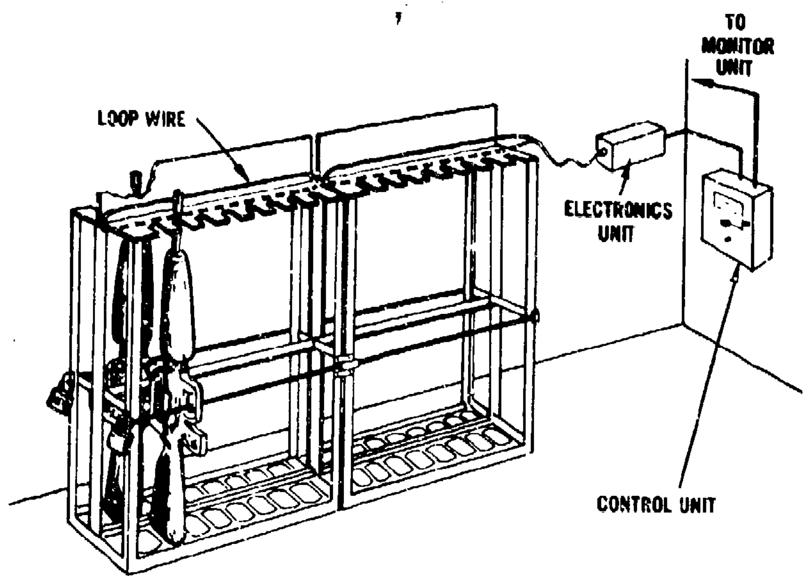

Figure 13. Magnetic Weapons Sensor

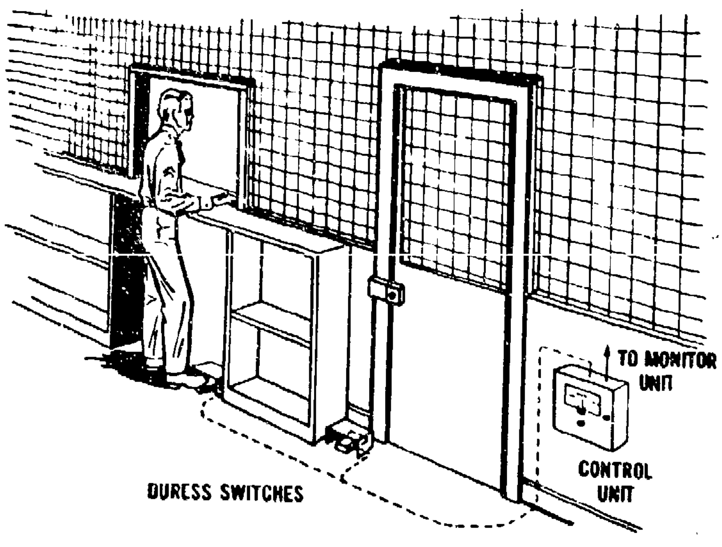

Figure 14. Fixed Duress Sensor

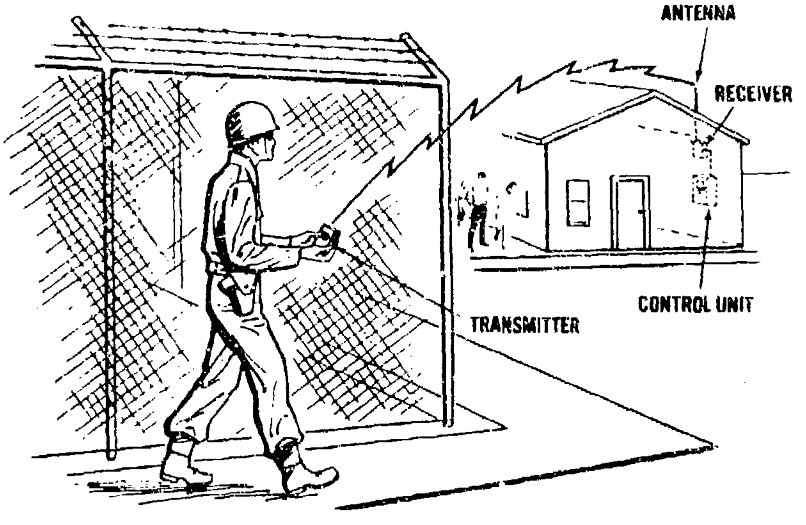

Figure 15. Portable Duress Sensor

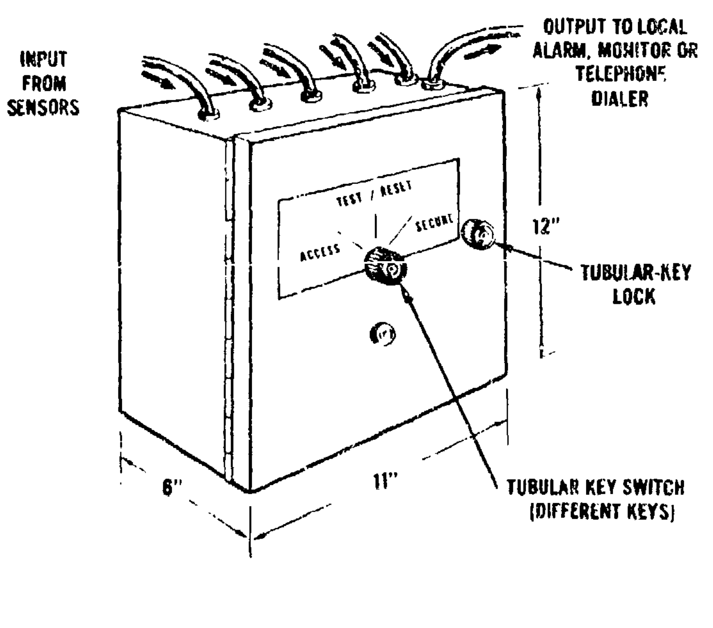

Figure 16. Control Unit For the System

signals to the local audible alarm and the monitor unit or the telephone dialer.

The Monitor Unit (Figure 17) is the primary notification device of the system. It receives the alarm, secure/access, and power status signals from the control unit and activates various colored lights on the display panel. Each monitor unit has a series of colored lights which indicates the status of the system. For example, the red-light-on would signify that an intrusion has been detected. A change in the status of any of the lights, corresponding to a change in the status of the control unit, is signalled by a flashing light and a buzzer. An acknowledge button allows the buzzer to be silenced and the flashing light to remain on continuously. The monitor unit also monitors the status of its own power supply and supervises the functional condition of the wires from all control units. The monitor unit is of modular construction and is designed to monitor from one to 25 locations.

The local Audible Alarm (Figure 18) is an electronics screamer for outdoor or indoor use in the vicinity of the protected area. It is activated by an alarm signal from the control unit via hardwire lines or by internal tamper circuits. It is also activated by its internal emergency power source when the line from the control unit is cut. After activation, the alarm will continue to sound until reset at the control unit, or in the case of a line cut, at the alarm itself.

The Telephone Dialer (Figure 19) is used only in those cases where a monitor unit cannot be used, since telephone line compromise will not be annunciated at the telephone monitoring location. The dialer reports an alarm when activated by an alarm signal from the control unit by automatically dialing one to three pre-selected telephone numbers and then automatically transmitting a recorded message indicating an alarm has occurred and identifying the location of the alarm. To eliminate the possibility of dialer line capture from an outside source, the telephone dialer is intended to be used with an "outgoing only" line.

This completes the discussion of the sensors and supporting components of the J-SIIDS System. Next, I will discuss the selection of these devices for use within various arms rooms.

The selection process is the main theme of the equipment application guide which was prepared under the auspices of DSPG by the CDC Military Police Agency, and is presently being distributed. The purpose of the manual is to provide guidance for the selection of interior intrusion detection devices which will be installed in military arms rooms. This manual applies to arms rooms of the military services within the continental United States and in worldwide situations where there are similar threat and installation environments.

It should be noted that within any base or installation, adequate protection for an arms room is dependent upon the construction of a particular arms room and the weapons racks, the alarm system reliability, and the reaction force responsiveness. These factors affect the overall security system of the particular arms room.

The equipment selection concept followed in the guide is to first describe to the reader the components of the J-SIIDS System and the operational principles of the various devices. Secondly, a survey of the arms room is made to determine the size, shape, and construction materials of the walls, ceilings, floors, doors, windows, ventilation holes, and other features of the arms room as an aid in choosing the proper mix of components. Thirdly, it provides guidance on how the various components can be selected to form the system which will provide the best protection and finally aid in the selection decision. With appropriate consideration given to arms room physical security environments, and using the survey information and the component selection information, the user can select the appropriate type and number of sensors and support equipment for his arms room.

In conclusion, Figure 20 presents an overview of the J-SIIDS Program. DA was tasked on 22 December 1971 by DSPG for the procurement of prototype models of the J-SIIDS. Delivery of prototypes is scheduled for September 1972. Each manufacturer will also deliver a proposal for production follow-on. These prototype units will be used for government and contractor testing during September through December 1972, with the production contracts awarded in October 1972, provided an appropriate Army "Type Classification" can be obtained prior to that time. DA has provided necessary funds for the initial production buy for the Army. Other services will be required to identify requirements and MIPR funds to the Army for initial production units. Delivery of first production items to the field could start in February 1973.

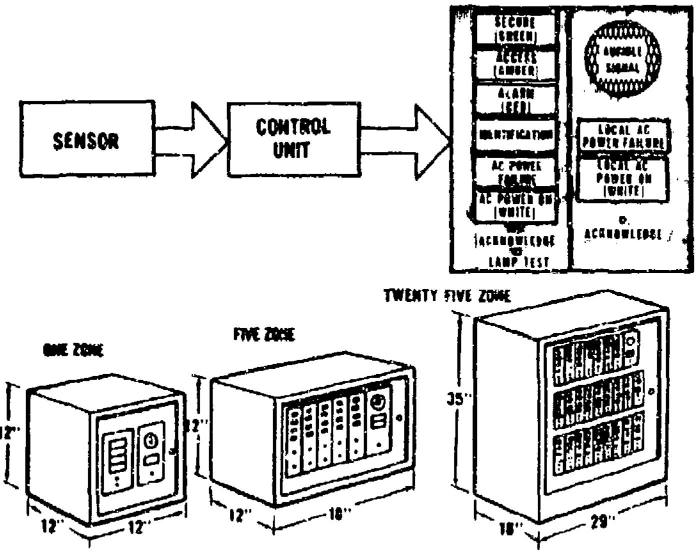

Figure 17. Monitor Units For the System

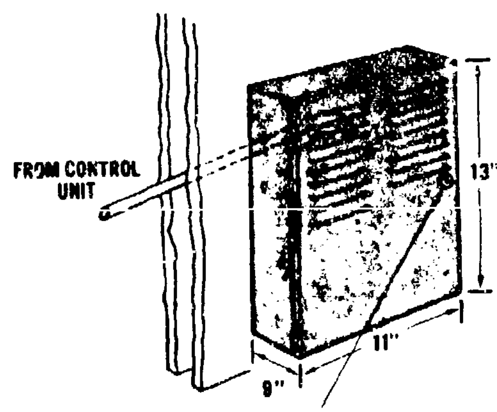

Figure 18. Local Audible Alarm (Electronic Screamer)

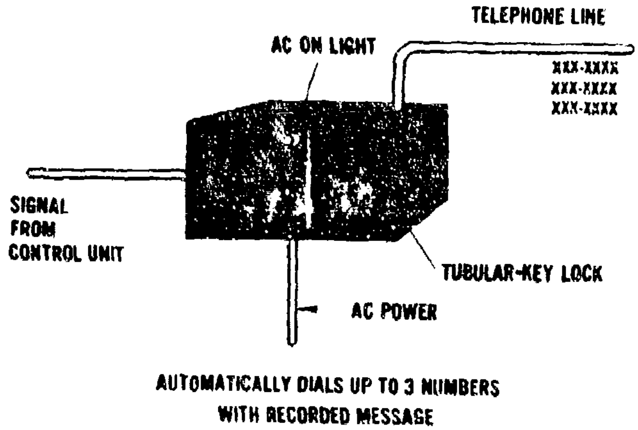

Figure 19. The Telephone Dialer

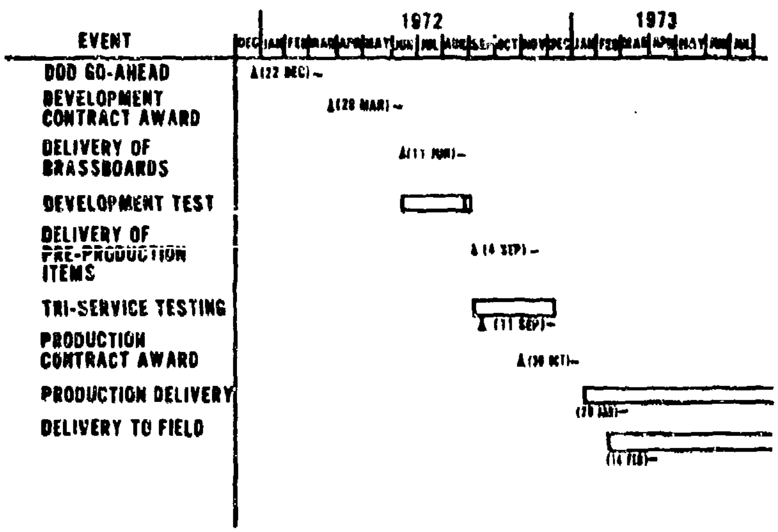

Figure 20. J-SIIDS Program Schedule

PSYCHOLOGICAL STRESS ANALYZER

By: Gerald Gallagher, Intrusion Detection Division, CM/CI Department, USAMERDC

Under current investigation at the Mobility Equipment Research and Development Center (MERDC) is a low-cost, portable checkpoint system consisting of a magnetic portable detector and a voice stress analyzer. The latter is designed to detect psychological stress as indicated in the human voice.

This system would be used in temporary or semi-permanent applications where use of the Integrated Access Control System would not be feasible. We would be using the system primarily to determine if a person were carrying a weapon. For example, the system could be quickly set up in a riot area to screen persons being detained.

A strictly military application would be the screening of refugees to determine if infiltrators were among the group. The simplest application might be at a restricted area, as shown in Figure 1. Here, a person would pass through the portal detector. If an alarm occurred, he would then be asked a few simple questions, such as: "Are you carrying a large amount of metal?" "Do you have any weapons?" Based on the stresses indicated in the answers, interrogation would continue or a physical search would be conducted.

Many methods of detecting psychological stress are available. One is the polygraph, which looks for changes in breathing, blood flow, and skin resistance. Other methods include eye movement, odor detection, etc. All of these techniques monitor physiological change induced by psychological stress. In our particular program we are looking for stresses indicated in the human voice. There appears to be a frequency modulation on the normal voice frequencies whose strength decreases with increasing psychological stress. These are believed to be the result of micro-tremors which are present in all voluntary muscles and which normally occur at a rate of 8 to 14Hz. These micro-tremors, it is thought, change the characteristics of the vocal tract, thus causing the frequency modulation (FM).

Figure 2 shows signals, after FM detection, from stressed and unstressed utterances. These charts were prepared by Dektor Counterintelligence and Security, Incorporated, Springfield, Virginia, during development of their Psychological Stress Evaluator. Note that the unstressed waveform is free-rolling, indicating the presence of the FM modulation. The stressed waveform lacks the free-rolling pattern, which indicates the lack of modulation.

The voice analyzer is similar to the polygraph in that it detects psychological change due to psychological stress. However, it has an advantage over the polygraph in that no sensor needs to be attached to the body. This permits a less formal test situation, which in turn tends to reduce test-induced stress.

The concept can be illustrated as shown in Figure 3. A test is structured to include relevant and irrelevant questions intermixed in such a way that a comparison can be made of the subject's stress reactions. The questions must be chosen carefully so that they are not in themselves stress producing, but rather that they produce a stress if there is any guilt reaction to them.

The test questions produce psychological stress, which in turn causes a physiological change. In our case, it would be a decrease in the frequency modulation of the human voice. The voice is recorded on a tape recorder and then played back through the Psychological Stress Evaluator (PSE). The output of the PSE is a strip chart recording which must be interpreted by a trained operator. The operator must relate the response to the test structure to determine areas of deceptive response.

MERDC is currently negotiating a contract with Dektor for the development of a Psychological Stress Analyzer which will be called the PSA. This will differ from the PSE-1 in that it will operate in real time, will require no tape recording, and will present a numerical output from 1 through 10 indicating the various levels of stress. This will eliminate the chart interpretation presently required and permit "real time" operation.

Extensive testing will be required to establish the validity of the PSA results and to determine if it will be applicable to the screening of persons in a checkpoint situation.

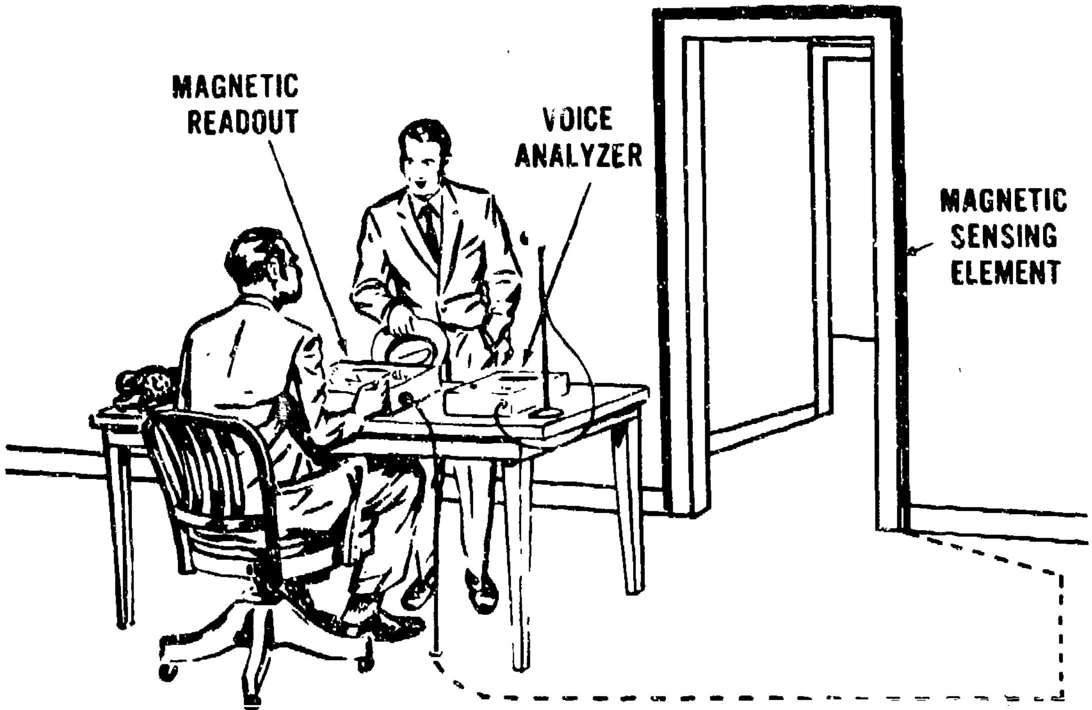

Figure 1. Passive Magnetic Detector With Voice Analyzer

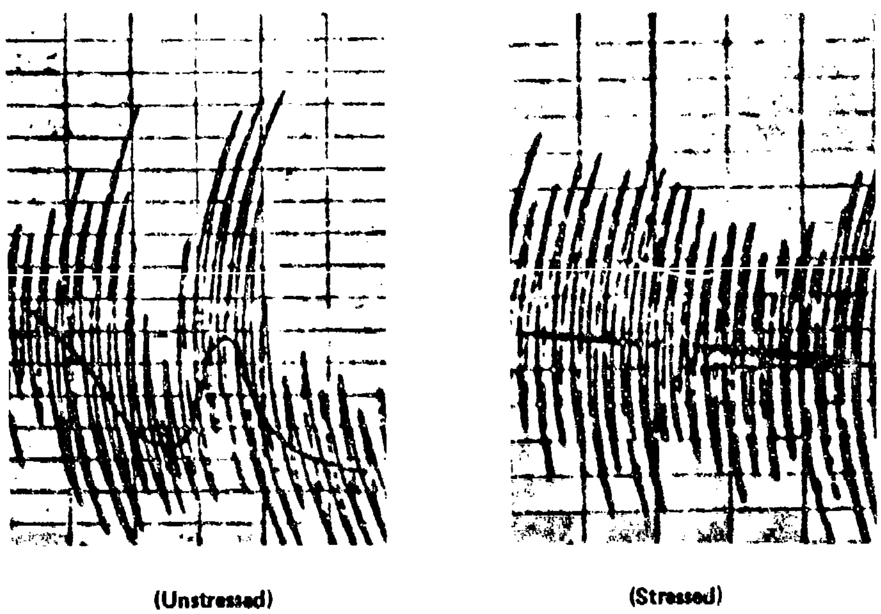

Figure 2. Stressed and Unstressed Signals After FM Detection

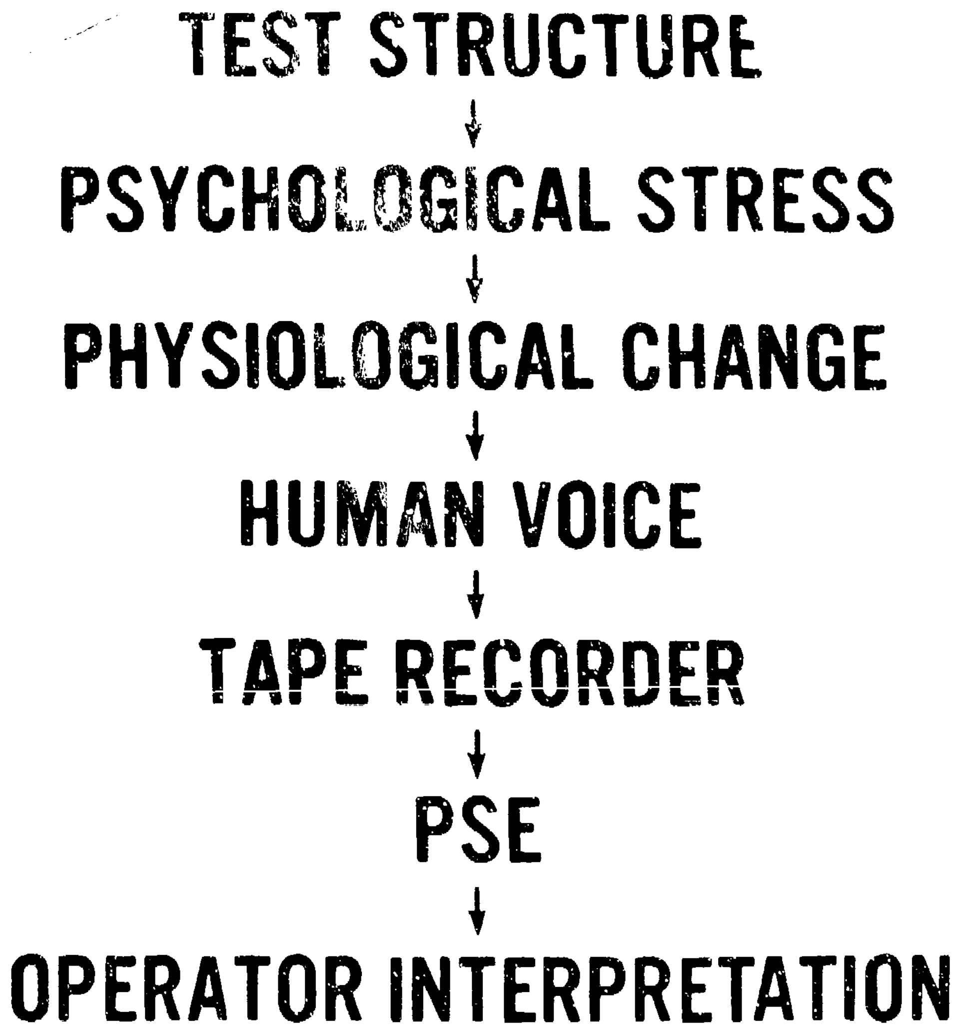

Figure 3. Test Structure Concept For Detecting Psychological Stress

PASSIVE AND ACTIVE ELECTROMAGNETIC DETECTORS

Chairman: Nicholas Mogan, Intrusion Detection Division, CM/CI Department, USAMERDC

Panel: J. F. Haben, U.S. Naval Ordnance Laboratory; J. H. Henry, Institute for Defense Analyses; A. L. Landman, Transportation Systems Center, DOT; C. Stewart, USAMERDC; Ken Yee, Law Enforcement Standards Laboratory, National Bureau of Standards

After the introduction of the panel members the chairman gave a brief summary of the proceedings. The discussions in which the audience actively participated covered mainly the following:

1. Detection performance versus cost
2. Detection of stainless steel weapons
3. Safety problems
4. Legal problems
5. Development of standards and application guidance
6. The need for obtaining more statistical data
7. Education of the general public
8. Application of hand-held detectors

The cost of presently available walk-through type detectors ranges from $800 to $6000. The passive detectors are under $2000 and the active systems above $1500. In general, the higher the price the better the discrimination capability between weapons and clutter items. But even the most expensive detector will not detect 100 percent of the weapons without at the same time detecting some of the clutter items normally carried by people. High detection reliability with a reasonably low false alarm rate can be obtained only if the people are separated from all hand-carried items, especially umbrellas, brief and attache cases, and women's handbags. Which detector is the "best" will be determined by the intended application. In those applications where people are not allowed to carry any metal (e.g., in prisons or in a mint), a very sensitive but relatively inexpensive active system should be used. If missing some of the smaller weapons is not critical, passive systems can be useful; but where personnel cannot be divested from metal clutter items and where high detection reliability is required, highly sophisticated active systems must be employed. Theoretically, it is possible to further improve the discrimination capability of the active detectors, but this would result not only in very high cost but also in a too complex electronic system, thus raising maintenance costs and decreasing operational reliability. Most likely, the use of a mini-computer would be the right approach; however, this would push the price even higher. There may be some applications, though, where even this high price can be justified.

Most of the stainless steels used for the fabrication of weapons (hand guns and knives) have magnetic properties; therefore, they are detectable with either active or passive detectors. But this means that the threshold level must be set lower, which results in more false alarms. Completely non-magnetic stainless steels or aluminum can be detected only with active systems, but again at the expense of relatively high false alarm rates from such items as keys, coins, etc., unless the people are divested of all metal. Here again, it was pointed out that when the safety of a key individual is at stake, every suspicious item carried through the detector must be identified. Inconvenience is not important in this instance.

Naturally, the non-technical general public is concerned with the potential health hazards to which they are exposed when walking through the detector, and with the potential damage to their possessions (electronic equipment, film, etc.). Passive detectors, since they don't radiate any kind of energy, have no effect at all on people or objects. Active systems, at certain frequencies and intensity levels, could have some effect, although the relatively low frequency and low intensity radiation employed in all known active walk-through type detectors has no physiological effect and won't damage a recorded magnetic tape. The only problem area which required further investigation was that of patients with implanted heart pacemakers. Therefore, both FAA and MERDC conducted extensive studies on cardiac pacemaker wearers with the result that none of the detectors tested represented any health hazard. Since the frequency and field intensity of the other commercially available detectors fall in the range of the detectors tested, we can safely assume that these detectors do not represent any health hazard. It would be very desirable for the users of active metal detectors if safety standards were developed and approved by the Department of Health, Education, and Welfare. The Law Enforcement Standards Laboratory is working on this.

Some groups believe that removing small arms from the street would solve a major portion of the crime problem. The question discussed was: "What are the legal barriers to utilizing electromagnetic detectors to find unlawful weapons on the street in the high crime areas?" No general answer was given to this question. There are certain situations where the use of detectors has been accepted by the legal authorities, for example, in screening passengers boarding an airplane or searching prisoners entering cells. According to at least one court decision the use of weapon det ; does constitute a search. The decision as to whether or not a search is reasonable can be different in each individual case depending on the conditions. What may be reasonable under one condition may be unreasonable under another. Even the military installations have some limitations. The days of "line'em up--shake'em down" are past, and the requirement for probable cause exists. If at an entrance to a confined area it is clearly stated that carrying firearms is prohibited by law, the use of weapon detectors may be acceptable. In case of a trial, it is under the judge's jurisdiction as to who is permitted to enter the courtroom. Therefore, in this situation detectors can be used if the judge so desires. The Maryland Gun Control Law has an amendment, the "Stop and Frisk" bill, which protects the police officer. If he has reasonable cause to believe that an individual is armed, he can stop him and make a search of the person. But whether or not the use of weapon detectors would be legal is unclear. One suggestion was: "Let's start to use the detectors in different scenarios and see what happens." Perhaps, this is the only approach which would lead to legislation that would update present public laws in this area.

The question was raised from the floor: "What kind of guidance is available for the users if they want to select or buy a weapon detector for a certain application?" The Department of Transportation (DOT) evaluated a number of commercially available detectors and the results were published in a report which included the manufacturers' names and the prices of the detectors. This report is unclassified and can be obtained from DOT. The Law Enforcement Standards Laboratory is presently working on standards for weapon detectors. This standard will be published in the near future.

The above mentioned documents are based mainly on laboratory test results. Operational characteristics under field conditions still have to be determined. In the past, weapon detectors were used extensively only in two scenarios: airports and prisons. In both situations the flow of traffic and the environment can be controlled reasonably well, but we have no experience as to how any of the detectors would work on the streets, at the entrances of public buildings, in hotels, theater lobbies, etc. It is extremely important that statistical data in the above and similar scenarios be obtained. Without these data, the full potential advantage of using weapon detectors cannot be determined.

The importance of the education of the general public was emphasized. The public must know that the detectors are completely harmless, that they won't damage anything that they are carrying, and that the use of the detectors is for their protection. Then the people will cooperate. As of this date, tens of thousands of people have walked through the weapon detectors as volunteers at various airports, and maximum cooperation was experienced.

The possibility of using small hand-held metal detectors to detect concealed weapons on people in crowds, such as those found at a political rally, was discussed. According to the opinion of some experts, the crowd is usually so dense that it is impossible to move around to scan people with a detector. But, since no other detectors are presently available for this scenario, it is certainly worth a try.

To summarize, a large variety of walk-through type detectors are available in all kinds of price ranges. Different applications require different detectors. To be able to select the right detector for any application, more field tests and more statistical data are required. The detectors are harmless, but the legal implications must be resolved.

EXPLOSIVES AND WEAPONS DETECTING DOGS

Chairman: Major R. M. Sullivan, Directorate of Security Police, HQUSAF

Panel: COL M. W. Castleberry, Director, Bio-Sensor Research Team, Walter Reed Army Institute of Research; Mr. Henry Knauf, CM/CI Department, USAMERDC; Mr. Sidney Michlin, President, United States Police Canine Association

Mr. Boneta

I would like to introduce Major R. M. Sullivan, representing the Air Force Security Police, who will conduct our panel discussion on canine detection.

Major Sullivan

Thank you. I would like to introduce the other gentlemen on the panel. To my right is COL Castleberry, Director of the Bio-Sensor Research Team, Walter Reed Army Institute of Research. Dr. Castleberry is the prime researcher for the development of improved military dogs through genetic selection to achieve breed improvement and temperament of the dogs. Dr. Castleberry is here to answer questions specifically directed to the type of animal that should be used for law enforcement operations.

To my immediate left is SGT Sidney Michlin, President of the United States Police Canine Association. This is a nationwide association of police officers who handle dogs on duty. At the present time, the association has some 800 members representing 30 states around the United States. SGT Michlin's expertise is in the operational aspect of a dog team on duty. That is, the organization and supervision of the police officer and his dog in any given situation, whether it is riot or crowd control, burglary detail, or bomb and narcotics detection.

My expertise is related to the selection and training of animals in the quantities needed by the military for law enforcement duties.

To my immediate right is Mr. Knauf, the prime researcher in the area of mine/booby trap and explosives/narcotics detection here at MERDC. He is looking into special uses of dogs in terms of weapons detection, mine detection, and explosives detection.

I would like to open this morning by commenting on the dog's ability, not only in the law enforcement role, but also on its ability to find mines, explosives, or narcotics. One area which I think deserves some consideration is the capability of the dog to perform in the active role of protection of public figures, such as area sanitization, sanitization of meeting locations, billet areas; and the physical protection of hotels, motels, and houses. The dog/handler team has the capability of clearing an area (sanitizing it), and keeping it clear during the period that you have a public figure under surveillance. The dog/handler team can also be used to establish protective barriers for crowd control and by denying entry into specific areas. This provides not only a good detection capability, but also a good psychological impact.

Other areas include the protection of vital resources that are necessary for the support of a public figure, such as communication sites or airplane security. The dog/handler team can provide security of a water supply in an area where someone could influence the health and welfare of the public by impeding the flow of water or contaminating the water supply. The last thing, of course, is riot and crowd control. I think we have adequately demonstrated that the dog is a viable detector in a number of areas if it is used properly. We ought to discuss, not whether or not the dog can do it, but how to use the dog in the most effective manner.

Consider the organization of the dog team, the unit itself. Can one bomb dog provided to the City of New York provide a 24-hour bomb detection capability in that city? Well, I think not, and most people agree. We ought to discuss how many dogs are necessary to provide this kind of protection and how many men it takes. What kind of a man should be the handler of a detector dog? Can anybody handle a trained dog and does one man become the handler of that dog? If so, does every dog require a handler? What are the requirements to maintain the capability of this animal? This is not a black box operation. You don't procure it, put it on a shelf, and use it when you need it. The dog has to be cared for. The TLC (Tender Loving Care) is an important requirement. If you don't provide the dog with proper training, proper food, proper living environment, and the tender loving care that the dog needs to work well, then you are not going to have a program very long.

Finally, I think we ought to talk about breed selection, and the health and nutrition that these animals require to make them an effective sensor. Before I open the floor to discussion, I will have each member of the panel speak briefly about his area. Dr. Castleberry, a few words on dogs?

Dr. Castleberry

Primarily, my job is to develop a line of dogs to meet the requirements of the QMDO (Qualitative Military Development Objective), Detector System, Military Dog. Based on a study performed by the University of Maryland under contract to the Office of the Army Surgeon General, we have settled on the German Shepherd. To meet this requirement, we are improving this animal's capability from the standpoint of its physiological welfare, specifically the hip displasia problem, through genetic selection. This may not mean much to you, but many dogs have trouble with their hips, and this is a genetically oriented problem that responds well to selective breeding. We also believe that the intelligence or trainability of the dog, as well as the dog's temperament, can be genetically improved. Now, to those of you who are not very familiar with dogs, these things may seem to be far out, but they have tremendous bearing on the trainability of the dog and the use of that dog, as well as the longevity of that dog after it has been trained. We are interested in providing a more trainable, physiologically better, dog than is now generally available for military use.

Mr. Knauf

Research at MERDC is directed toward solutions to problems in two areas. First, and that naturally receiving the prime emphasis, is mine detection. The second is protection of public figures. Under the mine detection program, the effort can further be categorized into the development of an interim mine detection dog, and the other is the long range studies to develop a detector system military dog.

To meet the near term requirements for an interim mine detection dog, MERDC is presently training dogs in cooperation with the Scout Dog Committee at Fort Benning. Subsequently, MERDC will direct the evaluation phase to determine how well the dogs can detect buried mines and booby-traps, under what conditions the mines can be detected, and what the limitations are of the dogs.

Long range studies include olfaction, physiological reactions to alerting stimuli, and man/dog interfaces. We are interested in olfaction to determine the limit of detectability of buried mines, and whether it is even possible for a dog to smell out aged targets. We are also interested in finding out what, if any, physiological change takes place in the dog when it detects a target, such as skin temperature rise, heart-rate change, or other phenomena, and how to monitor these reactions. The next step in the process is to telemeter an electronic impulse, corresponding to the reaction, to a central point, and remotely control and reward the dog when it makes a positive detection.

The improved man/dog interface, remote control of the dog, will assure the ultimate goal of an improved detector system capable of covert operation.

In the area of public figure protection, MERDC is investigating narcotic/explosives detection dogs and concealed weapons detection dogs. The narcotics/explosives detection dogs are being trained at Southwest Research Institute, and will be evaluated by MERDC to determine their detection capability. The weapons detection capability of dogs has been previously demonstrated against recently fired weapons;

however, MERDC is investigating the possibility of using small dogs, such as the miniature grayhound, for this task. The dogs will be carried in the arms of its handler for covert operation.

SGT Michlin

In October, I left the Canine Watch in Washington, D. C., to go out on the street as Sergeant in, more or less, the ghetto area of Northeast Washington. In this capacity, I had the opportunity to witness one particular instance where the dog/handler team really came into play. A street incident occurred the other night where officers responded to a street fight. It started out as an "innocent" fight, but soon the juveniles were throwing bottles at each other, and the policeman placed a trouble call. Several units had responded by the time I arrived, which was within a few minutes. A disorderly crowd had assembled and was attempting to take the prisoners away from the officers on the scene. A canine officer and his dog had also arrived and was able to contain the crowd without having the dog bite anyone, even though the crowd numbered about 150 to 200 people. This was a well-trained canine officer who maintained his composure and did not overuse the dog. This is one instance where the dog can be used in the protection of public figures; that is, by maintaining crowd control. The big thing is whether people in high offices will allow the dogs to control the crowds.

The big thing now is the explosive detection dog. The dogs can be used to search and secure an area where a guest speaker is to appear. You could be sure that the room was safe from an explosive device.

The biggest problem with getting enough dogs on the street is to train enough dogs. The United States Capitol had 12 dogs trained at the Washington, D. C., Canine Institute, but it came to the point: How many of these dogs are going to be bomb-trained? The Senate and House were fighting each other. One wanted only one dog bomb-trained; the other wanted all 12 dogs bomb-trained. This is impractical to protect the whole capitol. They should have at least attempted to train all 12 dogs because not all dogs are capable of learning this new technique.

Mr. Henry

I'd like to ask a question, perhaps of COL Castleberry. I've always been puzzled by the choice of the dogs that are generally used. Most of the missions that we are talking about involve scent, and you'd have thought that choice of dogs would tend to run to hounds, fox dogs, those that have been bred for a keen sense of smell rather than for a keen sense of sight and sound. Why is it that the police dogs and the Labrador always seem to get chosen?

COL Castleberry

I've been asked this question so many times; I sat here fully expecting it. It's a fair question. Why not use a Bird Dog which has a good keen sense of smell and has a lot of stamina; or why not use a Bloodhound. I bought Bloodhounds, the English Pointer, the German Wirehaired Pointer, and the German Shorthaired Pointer, and cross-bred them in many combinations. This was done at the University of Maryland previously. Briefly, the answer lies in that any dog that has any hound in him is a hard dog to train for any of the police techniques that are going to be used. Now, if you are just going to have a bomb dog, for example, and have the dog just waiting for a bomb call, perhaps a dog like a Bloodhound would be better. Strangely enough, there is no real proof that a Bloodhound has any more sensitive a nose than does the German Shepherd. Previously the British used a Labrador Retriever for tracking purposes in Singapore, and we subsequently got the dogs into Vietnam.

In talking and visiting with people in Germany, I found out that the handlers themselves prefer the German Shepherd and they were going to the German Shepherd for military and law enforcement use. The German Shepherd has just as good a nose, if not better, than the Labrador, and he uses his head in addition to his nose. The Labrador would run the patrol right into an ambush, and the dog would never know it. The German Shepherd has an extremely keen sense of smell and I think these gentlemen's (panel members) use of this dog will point that out.

One last thing, the Bassethound--the dog with the long nose that sniffles--snuffles a lot. Previously, LWL bought two Bassethounds, and I mildly objected to it because I knew there would be some difficulties with this animal. They worked with bomb detection a little over two years ago and they finally gave up. The dog could detect bombs, but if it didn't feel like working, that is, if nothing appealed to him or if he wasn't hungry, then he wasn't really sufficiently dependent upon an owner to appreciate "pet and praise" reward. This is the type of thing that brings about the necessity of using a dog that is quick, responsive, and is useable in more than one situation.

Mr. Knauf

As far as this mission is concerned, finding a bomb or a mine represents a completely alien thing to the dog. It doesn't represent food. A Bloodhound will track food, be it a bird or a squirrel, or even a human. This represents something he can bite on and chew on. The mine or the booby-trap is an alien thing to the dog and he needs a high intelligence to be trained and to be kept trained for this type of a mission.

Major Sullivan

I think the working dog handler's disagreement with food reinforcement occurs after training. We certainly have no objection to the use of food reinforcement to teach a dog certain tasks rapidly. We recognize this is a very effective laboratory procedure. It's most effective when you can't devote a handler full time to this dog. The German Shepherd works quite well for "praise and affection." When you have one man training a large number of dogs, or just two or three dogs, to perform tasks, particularly in the confines of a laboratory, it's difficult for him to provide a handout for each of these dogs. The food reward is also very effective to teach a dog certain tasks in mine detection. Certainly, he will find the metal under the ground faster if he's been trained to know that there is food associated with finding the mine. However, we feel that at a certain stage of the game, food reinforcement has to be replaced by the affection of that man for his dog, and the dog for the man. There are a number of reasons for this. A man and a dog live together, work together, and know each other well. The dog works better for his handler than a dog who is reacting to a bag of food. A dog only works for a bag of food when he is hungry. The food reward may work real fine in Minot, North Dakota, in the wintertime, but what about the Canal Zone when it's 90 degrees and the humidity is 90 percent, and where the dog can exist on a lot less food than it would eat if the weather was cooler? He may not be hungry enough to work. In a combat environment my analogy is: I don't want to go on a 10-mile hike with 5 miles worth of food. I think that the reinforcement has to change sooner or later with the dog working out of devotion to its handler.

In training some 6,000 dogs in the last 5 years we have never had to use food reinforcement to get the job done, primarily because we marry the man to his dog. No training is conducted until we have established what we call a "man-dog relationship." Once that is established, training is very easy. I don't think the German Shepherd reacts quite as well to food reinforcement as he does to praise and affection. If you own a German Shepherd, you know that dog would rather please you than eat. It's that simple.

SGT Michlin

I have to agree. I have worked with my dog and when we came on this bomb-dog program it was something new, an area where not much work had been done or had been successful. We really started to go towards the food because we became frustrated, but once we really started working with really good explosives and found out that the dogs would find them, we just pushed them to the limits, with plenty of praise. A dog is going to work slower once he has eaten, but he's still working.

Major Sullivan

Another area that Sid just touched on which I think has some value, and which I didn't mention, is in the field of nutrition. Of course, I'm not an expert, but it would appear to me that you certainly can't keep a food reward dog on a full ration, on a healthy ration. You've got to keep the dog hungry. So you are talking in terms of an 80 percent diet or a 50 percent diet. It would seem to me that if somebody fed me half of my caloric requirement a day and told me that if I went out and played football and that every time I made a good play they would give me half a sandwich, I'd find it more difficult to play good football than if I were healthy. I don't know if that is medically or physiologically correct or not; it would just appear to me that a healthy dog is a happy dog. I don't know, but I hear that on television all the time and I tend to believe it.

(No name stated)

When you referred to the man-dog relationship, I assume that is the phrase for the other type of training. Is it difficult to change handlers? Suppose a man leaves the service; what happens to the dog?

Major Sullivan

When the man leaves the service, we retrain the dog to another man. The degree of difficulty is dependent upon the dog, the new handler, and the capability of the man who is doing the retraining. Yes, we have great love affairs. We have people who reenlist over their dogs. We have dogs who go into their kennel and will not respond for periods of weeks because the handler is gone. However, the retraining is not that difficult. I would say that the normal patrol dog can be adequately handled by another handler in 2 weeks, and within 6 months they become an effective team. Our training program is 12 weeks for the man and dog, but we don't consider them a fully qualified dog team until about 6 months. We feel it takes that long before the man knows his dog well enough to know what he is trying to tell him, and the dog knows that man well enough to be willing to tell him. It takes time. We are fortunate that we normally have 3-1/2 to 4 years with our people, the man and his dog.

During the course of the dog's life in the military, we use three to five handlers. We switched handlers on 600 dogs in Vietnam in a year, with no real sign of depreciation. We have a standardized training program and every dog in the United States Air Force is trained in the same way, at the same school. The personality is changing but the technique remains the same. If you can say "sit down", "stay", "heel", and "come", and say it with any kind of reasonable assurance, the dog normally will react to the command. However, it may take a while for the dog to develop the affection for you.

One thing that must be considered when you use the dogs in a civilian environment is that you can't haphazardly train these animals. Someone has to control the formal training and the continuation training on a daily, weekly, or monthly basis, depending on the kind of performance your dog is giving and the mission requirements.

(No name stated)

In a search for explosives you have to make plants to see if the dog is still working, and the response to the dog finding the plant is the food reward. The dogs that I have seen operate were the New York City explosive detector team. Do you feel that the effectiveness of the dog would not break down by switching to the handler/dog affection relationship?

Major Sullivan

No sir. The technique that is being used is not to check if the dog is finding a bomb. It is a reinforcement. We never ask a dog to find a bomb unless he finds a bomb. If he starts looking for a bomb and doesn't find one, he gets very frustrated. The key to the dog/handler relationship is the praise reward. We use a bomb plant when an area is clean to reinforce the dog's behavior. If you walk on an airplane to find a bomb, you must carry a bomb on the airplane with you. If the dog doesn't find one, you've got to have a bomb to put there.

(No name stated)

What have you found to be the maximum effective dog operating time, in say, a building search? How long will he be effectively searching?

SGT Michlin

That's the toughest question. I always bragged about my dog because at the Capitol we searched continuously from 4 o'clock in the morning until about eight, on different calls in different places. Of course, nobody wanted to bring us any real explosives that time. We somehow got it in later and planted it in the bathroom. The dog had previously searched the bathroom, but he made a positive indication when he approached the explosive. I think that the safe limit is about 30 minutes and then you have to rest the dog or it will start false sitting. This is the problem in Washington now. They are getting so many calls to many different areas that some of the dogs are giving false indications. The bomb squad has to take explosives with them at every alert to assure that the dog finds a bomb on every mission.

(No name stated)

What explosives are your dogs trained to detect?

SGT Michlin

C-4, C-3, dynamite with black powder, and TNT.

(No name stated)

Smokeless powder?

SGT Michlin

Yes, at the time I was working there, which was 6 months ago.

Mr. Klein

What size of a dummy bomb do you use to reinforce the dog if he hasn't found the real thing? Do you always keep it the same or do you vary the size? Is there any value to improving the dog by getting him to find something a little bit smaller each time?

Major Sullivan

Our handler at Andrew's AFB normally carries about a half stick of dynamite, or a quarter pound of C-4. We use firecrackers occasionally to reinforce the black powder odor. That's a question that we really haven't answered satisfactorily. We don't know that if you train a dog on a half stick of dynamite whether his reaction to four sticks of dynamite would be the same. We don't have enough experience with real bombs yet to know what the dog's reaction is going to be.

We had some 357 bomb calls on Andrews since the first of the year. Two alerts were actual bomb threats; however, the explosives were not detonatable. The dog found a two-inch firecracker in a suitcase at the Andrews Air Force Base Hospital one night. Now, this was certainly a smaller amount of explosive than we normally train the dog to find. However, we don't know definitely whether the dog can find a small sample if it is trained on large explosive samples, or if the dog can find large samples if it is trained on small amounts of explosive. The same is true of heroin. If we train the dog on 6 percent heroin, we cannot be sure that it will find 90 percent pure heroin. It is an individual thing with your dog, and again the dog/handler relationship plays a large part.

Mr. Mogan

I have a question concerning the sensitivity of the dogs. My experience is that if a person is allergic to a certain odor he is also more sensitive to it. I know that they can desensitize people by medication. Can they use medication to make either people or animals hypersensitive to certain types of powders? Has any research been done in this area?

COL Castleberry

No, not to my knowledge. I don't know how one could medically hypersensitize an animal. You may have a very good point there. There is some ongoing work that Major Sullivan mentioned last night. It has to do with isolation of certain sensitive sense buds in the olfactory system. Would you want to elaborate on that just a bit?

Major Sullivan

There was a doctor in Washington who was working on this, but I don't know his name. This doctor has found that he can eliminate the capability of a rat to smell anything but the specific odor it is trained to detect. I have no idea how the doctor does this, since the report was given to me verbally. The doctor has demonstrated that he can totally isolate extraneous odors in the rat. I think that he does it by burning the olfactory capability out of the animal except for certain receptors. We have some people looking into this to determine the exact mechanism. In theory, it is possible to have a dog that could not smell anything but explosives; however, my first reaction to destroying a dog's olfaction capability is that you won't have a dog very long. The dog is a scent animal who lives in a world of scent. In my mind, it would be like blinding the animal. Although a desensitized dog may be a great bomb detector, the maintenance of that animal may be very difficult.

(No name stated)

Do you use any culling tests before a dog becomes a candidate for training? If so, approximately what are they? Also, the dogs that you start initial training, about what percent do you consider trainable or useable at the completion of your training period?

Major Sullivan

The DoD procurement system is based on a kind of "try before you buy" concept. We run a military induction program for the dogs which consists of a battery of physical and psychological evaluations. We reject, and have rejected historically, 50 percent of the animals that are presented to us each year. We buy five out of ten dogs. We have successfully graduated over 97 percent of the dogs we procure.

The dog trainers look at the dog from a temperament point of view, and at a number of other things. We're very fussy about the appearance of the dogs. We find that you can't take an ugly dog and make a kid happy with him. The boy that's going to be the handler has to feel that his dog is the best looking dog in that class. So, we cull ugly animals. We cull animals whose haircoats are too long or too short. We don't buy dogs that are oversensitive or overaggressive, nor do we buy the dogs that are undersensitive or underaggressive. We will buy a gun-green dog, but we will not buy a gun-shy dog. We determine whether the dog has the willingness to be trained and the willingness to bite. We want to know how well he responds to human affection. Many dogs are just so undersensitive that you can't get them to work unless you hit them with a 2 x 4, and we don't want to do that. There is a complete battery of tests. The medical and temperament evaluation of the dog at Lackland takes about 9 days to complete. This includes complete blood series, urine series, X-rays, and dental evaluations. The investment to evaluate the dog is approximately $700.

We buy dogs between 12 and 36 months old. Dogs less than 12 months old have too much puppy temperament, and we need a dog who is mature enough to give us a 50-minute span of attention, through a 6-hour class day, 5 days a week. We can't use a young animal who needs play time and a lot of rest time.

The average working life of a military dog is approximately 9 years of age; therefore, it is not economical to make an investment of $3,000 in the training of a dog older than 36 months. We do, however, retrain dogs. There is no problem in training a 6-year old dog. We accept males or spaded females. The rejection rate for females is about 70 percent, as compared to 40 percent for the males. We find that most females would rather be mothers than fighters.

(No name stated--Dallas Police Department)

You talked about the criteria for a dog. How about the criteria for the handler?

Major Sullivan

The Air Force requires that each dog handler be a graduate Security Policeman, so the prospective handler is put through some rather close scrutiny during the period of his basic training and police training before he enters the 12-week school. We don't force anyone to be a dog-handler. He must be a volunteer and has to fight to be admitted to the Canine School. Nine times out of ten that will do all the necessary culling. There are problem areas such as the guys with two left feet. Every time they get near the dog, they are stepping on him. They don't know how to praise the dog or can't transfer affection to an animal. They would like to, but the dog will just not react.

We make the handlers go through a 3-day ground school before they are allowed to see their dog. Meanwhile, they are being evaluated by their instructors. Some are culled right there. Others make it through ground school, but choke up when they hit the kennel for the first time.

Many dogs will not react to a certain handler, and there are individuals who do not like certain dogs. There are dominant dogs and handlers as well as submissive dogs and handlers. You can't have a dog leading the handler around, so we try to match a weak individual with a submissive dog and build the both of them together. Sometimes, we will try to give a very dominant dog to a similar individual. It becomes a big battle in the kennel; but if the handler walks out first, you are going to have a good dog.

(No name stated)

Why do you devoice the explosive dogs?

Major Sullivan

I don't devoice any dogs, sir. You'll have to ask the Army that.

COL Castleberry

I hate to admit it, but I didn't know we were devoicing them. The dogs are trained not to bark for obvious reasons. In a combat environment, you don't want to reveal your position.

(No name stated)

Are the dogs trained strictly on reinforcement or are they also trained by punishment?

Major Sullivan

We don't use punishment. We use correction, and there is a difference. There are certain techniques where you have to physically show the dog what is required. For instance, an underaggressive dog must be taught to bite. Many dogs want to bite but have been conditioned not to bite during their early years. Every time they attempted to bite, a newspaper would hit them, but now they must be taught that it is good to bite.

If you want a dog to be suspicious of people, you have to train him to be suspicious. You have someone sit in the bushes and snap a twig or make a noise when the dog approaches. If the dog doesn't show an interest, the guy comes out and switches the dog on the flank. After two or three times, the dog is looking, and with encouragement from the handler, the dog starts to show some aggression. The more aggression the dog shows, the more praise it receives. It isn't long before the dog is chasing the guy through the woods and biting as hard as it can. Only good things happen when it bites.

(No name stated)

I'd like to ask Mr. Knauf a question. Do I understand correctly that you were considering the training of dogs for the detection of weapons on persons? If so, could you comment on the mechanism by which you expect this to be accomplished?

Mr. Knauf

We will introduce the dogs to odors associated with handguns in much the same way we introduce the dogs to narcotics or explosives. Some of these odors are the combustion products of smokeless powder, gun oil, and the metallic odor associated with a gun.

COL Castleberry

I could answer you more directly. I became interested a few years ago when these airplane hijackings first started. I got a little standard poodle that I worked when we first started working with marijuana back in 1968. I used the same technique with my pistol, and I found that this dog would locate the weapon whether it was on you or whether it was in your briefcase, but only if it had been fired within the recent hour or if I had just cleaned.it. I thought that if this research was carried out with professional trainers on an extended basis, that perhaps there might be value in it. I do know that in a very rough and ready way, yes, it can be done. I think their (MERDC) idea of using a small dog and having a lady walk through a crowd may turn out.

Mr. Knauf

There is also the psychological advantage associated with publicizing a weapons detection dog. An individual carrying a concealed weapon might become nervous in the presence of the dog and this would provide the means for detection. It is well known that a dog can detect an individual who is afraid of it.

Major Sullivan

A good analogy is the marijuana dog program. Based on the publicity we generated in the military system on the 150 marijuana trained dogs, we can take a police dog to the terminal boarding ramp and the outbound troops will leave the marijuana all over the place. The dog is not trained on the narcotic, but the psychological impact of that dog being there causes the troops to empty their pockets in a hurry. We have what we call "amnesty barrels" in the center of the air terminal lobby, and tell the troops it is their last chance. We put the dog over by the boarding gate, load the plane, and then go back and just literally empty the barrel. Psychologically, this thing does have good crowd impact.

Mr. Boneta

I have one question of the Sergeant. You mentioned the crowd situation in Washington, and said the dog didn't bite. Who decides whether or not the dog bites?

SGT Michlin

The handler makes the decision based on the situation. All the dogs, as well as the handlers, go through the same school and must pass the graduation course, but it depends on how well the handler adapts his dog to the street condition.

The reason that the Police Canine Association was formed was to overcome the image of the snarling police dog being unleashed on a "peaceful" crowd. There are instances throughout the country where they are turning the dogs loose on crowds. This is based in a large part on the abuse the police officer receives at the hands of a surly crowd. There are only so many beatings you are willing to tolerate before you react. Also, the dogs are getting hurt. It's the officer handling the dog that is the biggest problem.

Major Sullivan

This certainly is not a civilian problem either. The biggest problem that we face in the military is to place a well-trained dog/handler team with somebody who doesn't know how to use it. Place the team with an airport manager, for instance, and if he doesn't use the team right you are wasting your time.

The most common fault is the refusal of the supervisor to take the guidance of the dog handler who has been trained to operate the sensing system. There are some very sad tales from Vietnam because the flight commander or platoon commander failed to use his dog team properly.

(No name stated)

We have a marijuana dog. Now you mention heroin. Can the same dog be used on heroin?

Major Sullivan

We issued an order the other day to our school to prepare a full course on heroin detection, limiting it to fully trained marijuana police dogs. The qualified marijuana dog will accept the training easier, and to a greater degree of success. The heroin dogs will also be marijuana qualified. There are people who tell me that you can't train a dog to do more than one thing, but our experience dictates otherwise.

COL Castleberry

I was also a big advocate of this idea myself until I became acquainted with the Air Force concept. The limiting factor is your ability to keep the dog trained. The dog must be worked daily on the substances it is trained to detect. If the dog isn't worked daily, it is going to become desensitized to the odor. The same is true of the patrol dog. It must be constantly worked to maintain its alertness. It becomes a question of how much time you can devote to the continual training of your dog.

Mr. Brodie

Our department was thinking about getting some dogs. As you know, the police department has a limited budget, so they were thinking of getting the same dogs to smell explosives that smells marijuana. Do you see any drawbacks to it?

Mr. Knauf

The dogs that MERDC has under the PKPF Program are being trained on nitroglycerin dynamite, ammonium nitrate dynamite, C-3, and heroin. We have not encountered any problems.

(No name stated)

I wonder if you could comment on the inherent reliability of the animal as a function of the target that he is expected to detect? Are they better on certain types of drugs than they are on certain types of explosives?

Major Sullivan

During the training phase, we have found that it is easier to teach a dog to find marijuana than heroin. The heroin has a much lower vapor pressure; therefore, there is less odor associated with it. The same is true of explosives Nitroglycerine dynamite or C-4 is much more volatile than TNT and, consequently, they have a stronger odor. If you train the dog on the odors and keep him motivated, then he is going to find it. The dog must have the desire to work for you. You can't put him on a conveyor belt for 8 hours and ask him to smell all the marijuana coming through the post office. The dog will work at this task for several hours, but enjoys patrol work better. The dog will scout for 6 hours because it knows that at the end of it he is going to get a "bite'em." The incentive time is different, so you work the dog for different periods depending on the search.

COL Castleberry

The explosives or narcotic detection technique is a whole lot like tracking. Once the dog knows what you want, he will track it down. I think that this is analogous to the fact that the dog was able to go from marijuana to TNT in 6 days. (Dog used for PKPF Symposium demonstration). You point out what you want, and if it is a good, reliable dog with a good dog/handler relationship, then it's not difficult to introduce the new odor to the dog.

Major Sullivan

That's exactly why we decided to use the marijuana trained dog for the heroin detection. The dog was trained to marijuana and knows the search technique. Introduce the dog to the odor and we save ourselves time and money.

Mr. Newhouser

Have you found any interference from the jet fuels when working an explosives detection dog at an airport, and does the noise level disturbance degrade the effectiveness of the dog?

Major Sullivan

I can't answer your question specifically. We have a lot of researchers asking those questions. For instance, we don't know what the threshold scent of marijuana is through the masking odor of burning JP-4 fuel. It's the same with audition problems. We know that the longer a dog is exposed to the noise of a B-52, the less the noise seems to interfere with its ability to work. According to the studies at the School of Aerospace Medicine, the longer a dog works in a particular environment, the more adaptable he becomes to it. However, much depends on the dog's training and its motivation.

Mr. Boneta

I hate to interrupt something that is going so well, but we have two other s waiting. Thank you very much, Major. Thank you, panel members.

HUMAN BEHAVIOR ANALYSIS

Chairman: James H. Henry, Institute for Defense Analyses (IDA)

Panel: G. Gallagher (MERDC); James Wallen (MERDC); Dr. J. T. Dailey (FAA); J. H. Henry (IDA); Dr. J. Orlansky (IDA)

Chairman James H. Henry convened the Human Behavior Analysis Panel and introduced the panel members.

Dr. John Dailey from the Federal Aviation Administration (FAA) traced the etymology of the word "hijacking" back to its American origin. The word originated from the command that holdup people gave their victims, which was: "Hold'em up high, Jack." This eventually became "high jack." Dr. Dailey then gave a brief history of air piracy from the earliest reference to the present day. Air hijacking occurred as early as the mid-1920s when Arab groups operating in the Spanish Sahara captured French Airline planes and crews and held them for ransom. The first hijacking attempt of record on an American plane occurred in 1930. In those days, some Alaskan Airlines systematically searched their passengers. Their pilots were also armed. Dr. Dailey pointed out various motives for hijacking throughout its history: financial, political, and for kicks. Almost all motives for hijacking have historical precedence. The only thing new in hijacking is the person who does it for kicks.

While details of the "Hijacker Profile" could not be devulged, Dr. Dailey attempted to give the attendees a feel for the concept. The profile was developed so that attention could be systematically focused on a small fraction of the public. Studies were made 3 years ago on past hijackers. These indicated that hijackers had certain commonalties which were extremely different from the flying public. He explained that the profile doesn't really identify hijackers, but rather, it identifies successful people. Approximately 99 percent of the passengers are cleared by the profile. The profile has described 88 percent of the hijackers and has detected a much larger number of other criminals. Since the "Hijacker Profile" is based on things that are under the voluntary control of an individual, the actual makeup of the profile is guarded with a high degree of security.

Mr. Quine of Picatinny Arsenal pointed out that a person native to an area is very often more capable of recognizing the anomalies of a situation involving the protection of a public figure than a person who is brought into an area from outside. In addition, he suggested that the symposium attendees take a positive attitude, saying: "The one thing that will do more good than anything else is to have people think we know a lot more about detection of weapons and detection of persons." Further discussion expressed the need to convince the public that current methods are effective. The deterrent effect of the presence of detectors was also pointed out.

Following this discussion, questions were solicited from the floor on the Psychological Stress Analyzer (PSA), which had been the subject of previous talks. The discussion centered on the limited validation to date on the system and the applicability of the system to some specific situations. Dr. Orlansky of the Institute for Defense Analyses (IDA) explained the factors which are required for a polygraph examination and pointed out the lack of a baseline applicable to highly truncated test situations. It was explained that the aim of the MERDC program is to determine the applicability of the PSA to the Protection of Key Public Figures (PKPF) Program. It was generally agreed that the validity of the PSA remains to be proved.

Concluding the panel discussion on Human Behavior Analysis, Dr. Dailey responded to a series of questions from the floor on the Gate Plan. He explained that the profile was one part of the Gate Plan and that it had been applied to approximately 50,000,000 people thus far. One percent of these people are not cleared by the Profile, and of these approximately 50 percent are stopped for an interview, asked for credentials, and asked questions. Most of those are then cleared. Approximately 2,000 persons have been arrested as a result of this activity. This includes a large number of criminals other than hijackers. Very conclusive evidence exists that 10 or 12 cases involved the intention to hijack. Dr. Dailey estimated that 65 percent of the hijacks last year could have been stopped had the Gate Plan been fully implemented.

X-RAY INSPECTION SYSTEMS

Chairman: Dr. D. B. Ebeoglu, Air Force Armament Laboratory

Panel: L. Barnes, Picatinny Arsenal; T. Brodie, Dade County (Florida) Public Safety Department; R. F. Bundy, Department of Transportation; R. G. Cumings, U.S. Postal Service; Major G. Lodde, U.S. Army Surgeon General's Office; C. R. Newhauser, International Association of Chiefs of Police; L. Nivert, USAMERDC

The application of X-ray inspection systems to the Protection of Key Public Figures (PKPF) is in two basic areas: (1) search of people carrying weapons, and (2) examination of hand-carried bags and packages. The first problem is being investigated by the USAMERDC group only. On the other hand, all of the agencies represented on the panel have developed instrumentation to solve the second problem. The threats to be detected were defined as guns, knives, and explosives. Some distinction was made between the PKPF problem and the one facing the FAA, the Postal Service, and Customs. Those differences included the number and sizes of packages or bags to be inspected, the limitation of threat material to be detected to those items listed above, the rate and frequency of inspection, and the type of location at which the inspection would be carried out.

Introductory remarks were presented by the members of the panel, each giving the rationale behind the current state-of-the-art in electronic radiography and the particular requirements of his agency. The concern in all cases was keeping the dose to packages low enough to prevent fogging of undeveloped film and meeting radiological public health regulations on the use of X-ray machines. All the agencies had the problem of inspecting large numbers of items in a short period of time. Hence, systems that could yield an image in real-time, or close to real-time, were sought. The only difference, insofar as the problem of the protection of key public figures is concerned, was the need to examine smaller packages like handbags and attache cases.

Both fixed and portable systems have been developed by the agencies. However, low weight and portability have caused loss of detail or resolution in the radiographic image. For this reason, the panel has recommended the use of a fixed system in permanent installations, such as the White House or the Capitol Building.

The question of the advantages of radiography over visual inspection was raised. In response, the panel cited examples of inspections made of the inside of seemingly solid objects, such as dolls and knife handles. Radiography permits the rapid inspection of large areas of packages for suspicious inclusions. It can thus be used as a culling tool to eliminate packages that have no possibility of a threat in them. The present systems are being evaluated with this purpose in mind. The objective is not to perform a detailed analysis. However, two areas of uncertainty exist. The first involves the lack of statistical information on the percentage of packages that could be passed without being opened. The second is the lack of knowledge on the probability of finding explosives that would be passed over. These two areas would have profound effects on the selection of design criteria for radiographic inspection systems and should be thoroughly explored and established. The time required to examine effectively and realistically numbers of people and quantities of packages has got to be determined.

The bomb disposal experts on the panel reviewed the type of explosives they had encountered in their careers. It was agreed that there was a great variance in the types of bombs constructed in the United States. There were, however, some standard types that could be found in particular regions (for example, the area of New York City). The experts stressed the need for rapid recognition of bomb components by means of good, clear, sharp pictures in light of the large differences found in the types and densities of explosives and fuses.

As was shown in the demonstration the day before, there are some explosive devices that are not detectable with present radiographic systems. These are not exotic devices. Information on these devices was published by the Government 5 to 10 years ago The need for higher definition in the current radiographic systems was stressed. The need for more training in bomb recognition was also suggested, as was training in the basic understanding of what can be done with X-rays and with specific radiographic equipment. A clearing house of information for government agencies was proposed where needs and applications would be resolved into a set of specifications. The opinion was expressed that such a center could provide a better weighting of a particular system for a particular purpose.

The question of automating an X-ray system to eliminate the inspector was raised. It was generally felt that this was a little bit "pie-in-the-sky" at this point. With the random orientation of even the simplest threat object, such as a gun in a briefcase, it is highly unlikely that a complex image analysis could be carried out in the foreseeable future.

The problem of finding a threat secreted in a structure, such as in the walls of a building or an airplane, was presented. It was generally agreed that there was no known technique for finding such objects quickly and reliably. The possibility of using dogs for localizing a threat, and X-rays for identifying it, was suggested. It was not clear whether this would be effective or even feasible.

Opinions were expressed as to the usefulness of the personnel inspection system. The general feeling was that although the system appeared promising, it could only be used under extremely covert government-controlled circumstances. There would be legal difficulties in using it on the general public. The need for establishing performance standards for such a system and for legislation to update present Public Laws is clear. In general, the need for reducing the yearly dose to the population and the need for personnel inspection are diametrically opposed. Thus, it is necessary to use a precursor ahead of the X-ray system, such as the electromagnetic device, and to keep the dose as low as possible. In the meantime, the legal or legal-medical position remains to be defined.

To summarize, there now exist some very valuable state-of-the-art systems that can help reduce the probability of clandestine threats being brought in to a fixed location to harm key public figures. Much of the effectiveness of the currently available equipment will depend on the training, experience, and skill of the operator, not only to expose the item but also to interpret the images. There is clearly a need for additional resolution, contrast, and reliability. These demands could result in an increase in cost and possibly an increase in size and weight of the equipment. Performance criteria, application techniques, and the proper environment for optimum use of the systems must be developed. The equipment must be field-tested to provide a statistical data base from which probabilities of detection can be obtained. It is recommended that potential users of radiographic systems spend as much of their resources on training and on developing techniques as they do on selecting and buying equipment. Lastly, standards and procedures must be developed if acceptable and repeatable performance levels are to be achieved. Quantitative tests of radiographic systems must be evolved for inspection. It cannot be expected that the manufacturer, or even a central agency, can develop all the necessary standards and procedures. Thus, it is important that both developer and user agencies devote adequate effort to ensure that X-ray systems are used effectively.