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DEPARTMENT OF DEFENSE
OFFICE OF SECURITY REVIEW
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

September 27, 2011
Ref: 11-I-0018

The Department of Defense is hereby releasing to you two documents under your eleventh mandatory declassification review (MDR) appeal filed with the Interagency Security Classification Appeals Panel (ISCAP) as appeal 2005-013. The documents have been declassified in their entirety per the ISCAP decision that was conveyed to you in the attached ISCAP letter of August 22, 2011. If you have any questions about this case, please contact Mr. David Daley at (703) 614-4925.

Sincerely,

M. M. Langerman
DoD ISCAP Liaison

Enclosures:
As stated

cc:
Interagency Security Classification Appeals Panel
Under Secretary of Defense for Intelligence
Washington Headquarters Services Records and Declassification Division

COPY

Interagency Security Classification Appeals Panel

c/o Information Security Oversight Office
700 Pennsylvania Avenue, N.W., Room 100
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August 22, 2011

Reference: ISCAP Appeal No. 2005-013
DTIC Report Nos. AD510086, AD410085, AD015218

Mr. Reginald D. Hyde
Deputy Under Secretary of Defense for
Intelligence and Security
OUSD (Intelligence), Room 3C915
5000 Defense Pentagon
Washington DC 20301-5000

Dear Mr. Hyde:

Please be advised that the Interagency Security Classification Appeals Panel (ISCAP) has concluded its consideration of the eleventh mandatory declassification review appeal filed by and that the sixty-day period during which an agency head may appeal an ISCAP decision to the President has expired. Enclosed are copies of the documents and a chart that outlines the ISCAP decisions. Your agency must release all information declassified by the ISCAP to the appellant, with the exception of any information that is otherwise authorized and warranted for withholding under applicable law. Please provide the ISCAP staff with copies of the documents as released to the appellant. If you have questions about this appeal, please contact William C. Carpenter or Christopher O. Hofius at (202) 357-5250.

Sincerely,

John P. Fitzpatrick

JOHN P. FITZPATRICK
Executive Secretary

Enclosures

ISCAP DECISIONS

IDENTIFYING NUMBERS	DESCRIPTION OF DOCUMENT	ACTION
document 1 ISCAP Appeal No. 2005-013 DTIC Report No. AD 510086 AD 410085 AD 015218	Compendium Interagency Conference on the Tunnel Problem April 3, 1968 69 pages Confidential	DECLASSIFIED THE DOCUMENT IN ITS ENTIRETY
document 2 ISCAP Appeal No. 2005-013 DTIC Report No. AD 510086 AD 410085 AD 015218	Compendium Interagency Conference on the Tunnel Problem October 29, 1968 109 pages Confidential	DECLASSIFIED THE DOCUMENT IN ITS ENTIRETY

~~CONFIDENTIAL~~

AD510085

COMPENDIUM

INTERAGENCY CONFERENCE ON THE TUNNEL PROBLEM (U)

3 April 1968

STATEMENT #2 ~~CLASSIFIED~~

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of ____________

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RESEARCH AND DEVELOPMENT

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COMPENDIUM

INTERAGENCY CONFERENCE ON THE TUNNEL PROBLEM (U)

3 April 1968

Brigadier General Charles D. Y. Ostrom, Jr.

Chairman

Dr. Ivan R. Hershner, Jr.

Deputy Chairman

Dr. James I. Bryant
Action Officer

CONTENTS

~~CONFIDENTIAL~~

PREFACE

In December 1967, a Staff Study of the requirements and/or programs of the Army, Navy, Air Force and ARPA for tunnel detection capabilities was completed. In this study, it was recommended that a cooperative coordinating committee on tunnels be established to coordinate activities between the Services for developing devices and systems for tunnel detection, denial and destruction.

The contents of this compendium are the reports of the First Interagency Meeting on Tunnels held at the OCRD Highland Building, 3 April 1968. In general, the contents can be considered representative status reports of the tunnel R&D programs of the Services. Technical reports of the agencies and laboratories purposely have been omitted from the compendium for reasons of convenience. However, the complete mailing addresses and telephone numbers of all the participants are included to serve as an expedient in communicating.

This compendium makes available a permanent record of the conference proceedings. It is intended that the contents will provide for the participants a useful reference and guide in the planning and direction of future tunnel programs.

IVAN R. HERSHNER, JR.
Chief, Physical and Engineering
Sciences Division

Editor's note: To assist further in communicating program information, it is requested that a copy of pertinent technical reports on tunnels be submitted to this office as they become available. A listing of the reports will be distributed periodically to the conference participants.

AGENDA

0900 - 0930 - Introductory Remarks

0930 - 0950 - U.S. Army Materiel Command: Tunnel Programs and Responsibilities

0950 - 1010 - Tunnel Detection Program at Mobility Equipment Research and Development Center (MERDC)

1010 - 1030 - Limited War Laboratory's Tunnel Detection Program

1030 - 1040 - Coffee

1040 - 1100 - Waterways Experiment Station's Tunnel Program

1100 - 1130 - Air Force Tunnel Requirements and Programs

1130 - 1200 - Marine Corps Tunnel Requirements

1200 - 1300 - Lunch

1300 - 1330 - Navy Research and Development Programs Related to Tunnels (not presented)

1330 - 1400 - Tunnel Programs Sponsored by the Advanced Research Projects Agency (ARPA)

1400 - 1430 - National Aeronautics and Space Administration (NASA) Research and Development Programs Related to Tunnels

1430 - 1440 - Coffee

1440 - 1500 - Defense Communication Planning Group's Program Related to Tunnels

1500 - 1600 - General Discussion: Coordinating Future Tunnel Programs

INTRODUCTORY REMARKS

Brigadier General Charles D. Y. Ostrom, Jr.
Director of Army Research

Welcome to the Army Research Office.

The principal objective of this meeting is to bring together representatives of laboratories and agencies having responsibilities for the development or the provision for operational use of equipment and systems for the detection, denial and destruction of enemy tunnels. It is hoped that each of you by participating will get to know better your counterparts in your sister agencies, to know what each agency's objectives and responsibilities are, and to know the functions and activities in which each is engaged, or might be engaged in the future.

This conference is one of a series of activities conducted by the Army Research Directorate since assuming staff responsibility in December 1966 for monitoring Army R&D efforts related to tunnels.

In June 1967, a report entitled "The Tunnel Problem", authored by LTC Magill, was completed and distributed to qualified and interested agencies. This document described for the first time in a detailed manner, the technical aspects of the tunnel threat in Southeast Asia and the Army's efforts to generate equipment and systems to counter that threat.

In December 1967, a Staff Study on tunnel detection was completed. This study, of which most of you have copies, summarizes the requirements, the technical and administrative aspects of the Army's research and development tunnel programs, and finally the present technical capabilities available for meeting the problems of tunnel detection, denial and destruction. In addition to reviewing the tunnel programs of the Army, the study also reviewed those of the Air Force and ARPA. During the preparation of the study, tunnel briefings were given to and received from representatives of the Marine Corps and the Navy.

The Staff Study indicated that considerable progress has been achieved in a relatively short time period, particularly when one considers the rather small program effort which has been directed toward such a complex problem. The problems of tunnel denial and tunnel destruction have already begun to give way to these R&D efforts. The much more difficult problem of tunnel detection appears to be more reluctant to yield to the R&D effort which has been applied to date.

The third activity consisted of an Army-wide Tunnel Conference which was held here on 12 February 1968. At this conference for the first time, both the technical and administrative aspects of the Army's Tunnel Program were reviewed in regard to requirements, objectives, resources, coordination and future planning.

With the feeling of somewhat greater insight into the Army's Tunnel Program, planning was initiated for the Interagency Tunnel Conference which is convening here today.

The basic objective of this conference is to provide a mechanism for coordinating the tunnel programs within DOD. By each agency working in its own area of responsibility, and within a planned program for coordination, the component activities can be most responsive to specific needs, and R&D resources can be utilized with maximum effectiveness.

Again, I welcome you to the Army Research Office, and may today's meeting be helpful and productive.

Army Materiel Command: Tunnel Programs and Responsibilities

Major Joseph Tedeschi

This presentation will cover the AMC role in the Tunnel program to include requirements, functions, and R&D activities.

AMC presently has the following four-fold tunnel program:

PROGRAM	RESPONSIBLE STAFF ELEMENT
1. Detection	Individual and General Equipment Office, Development Directorate
2. Destruction	CBN Office, Development Directorate
3. Denial	CBN Office, Development Directorate
4. Exploration Kit	Major Items Directorate

I will cover the tunnel destruct, denial, and exploration phases of the program. Mr. Damgaard of the Individual and General Equipment Office will follow my presentation and brief you on the AMC program on tunnel detection.

Tunnel Destruction

Work is being done at Munitions Command/Picatinny Arsenal - Initial requirement for this work received in Feb 1965 under ENSURE #111. The first AMC approach to satisfying this requirement was the XM 69 Acetylene Generator Tunnel Destruct Set. (NOTE: At this point in the presentation, a brief explanation of the characteristics and capabilities of this set was given)

450 XM 69 sets were shipped to Vietnam starting in November 1966. In January 1968, the following evaluation of the XM 69 was furnished by USARV:

1. Tunnels with overburdens of more than 5 to 8 feet are not effectively destroyed.

2. The acetylene is not distributed evenly throughout the tunnel complex resulting in incomplete destruction of tunnels.

3. There is danger of premature detonation of the acetylene.

4. The set contains too many components.

5. The liquid oxygen and water used with the set are not always readily available.

USARV concluded that the XM69 is less efficient than other demolitions normally used to destroy tunnels, and recommended that R&D efforts be expedited to provide a more suitable tunnel destruct system.

In response to this USARV recommendation, work is currently underway at Picatinny Arsenal to develop a follow-on tunnel destruct system known as LETUDS (Liquid Explosive Tunnel Destruct System).

Liquid explosives are being considered for tunnel destruct purposes for the following reasons:

(1) From Bureau of Mines studies, there appears to be a natural limitation to the amount of chemical energy available from hydrocarbon fuels. This amount of energy will only destroy tunnels with overburdens of 2 to 3 meters. The requirement stated by USARV is to destroy tunnels with up to 10 meters overburdens.

(2) Since it does not appear possible to configure means to derive enough chemical energy from gaseous hydrocarbon fuels to destroy tunnels with overburdens of more than 2 to 3 meters, the logical move was to a condensed phase or liquid explosive. (The exception to this might be the use of nuclear energy to destroy tunnels.)

It is not expected that LETUDS will satisfy the USARV desires for a lightweight, man-portable device to destroy tunnels on search and destroy missions. It is just not possible to devise a small enough package to do this job under the conditions imposed by search and destroy missions. It must be recognized that destroying tunnels of reported depths and lengths is a deliberate and time-consuming process. It is with this concept of use in mind that LETUDS is being developed.

A prototype LETUDS system was successfully demonstrated at a test conducted at Paris, Pa. in July 1967. Briefly, LETUDS consists of lay flat, plastic tubing deployed into a tunnel by trained personnel using a Drag Pack (a device slung from the stomach or rump which "pays out" the tubing as the "tunnel rat" crawls through the tunnel). The tubing is then filled with PLX (Picatinny Liquid Explosive - 95/5 Nitromethane/Ethylenediamine) dispensed from its shipping containers by a pumping system. When the last despenser is empty, the liquid explosive will be capable of destroying 1000 feet of tunnel with 10 feet of overburden. Present plans call for shipping 30 sets to Vietnam in June 1968. A demonstration team will accompany the sets to Vietnam.

Tunnel Denial

Work is being done at Munitions Command/Edgewood Arsenal. Initial requirement for this work received in November 1965 under ENSURE #8.

Two separate requirements are identified:

(1) flush people out of tunnels

(2) long term denial of tunnels (30 days or longer) in those cases where tunnel destruction is not feasible.

The tunnel flushing problem appears to be satisfied. The technique of using a burning type CS grenade, a poncho over the tunnel mouth, and the Mit Mite blower has proven to be successful in flushing people out of tunnels.

Various approaches have been tried to solve the long term denial problem.

1. Foams - gelatin and urea-formaldehyde foams were investigated in an attempt to achieve a rigid, reticulated foam within which agent CS could be suspended. Total fill of tunnel with foam was planned. Efforts were successful in formulating foams that would stay rigid for two months. However, this effort was not investigated further in light of the more promising approaches that evolved.

2. Nettles - A small, barbed spine of the cactus plant Rufida was investigated as a possible denial agent. An individual crawling through a tunnel seeded with this material would undergo sufficient itching and discomfort to deny use of the tunnel. Again, this method was dropped in favor of more promising approaches.

3. Agent CS-2 - A modification of the riot control agent CS1 with the unique property of hydrophobicity (no affinity for water). Tests indicate that CS2 blown into tunnels will remain effective in denying tunnels for periods up to 90 days. This appears to be the most promising approach to tunnel denial, and plans are presently underway to type classify the agent for this purpose.

The M106 Mity-Mite blower is limited in its capability to dispense agent throughout the deeper and longer tunnel complexes being found in Vietnam. Under ENSURE #34, the requirement has been established for a large capacity tunnel flusher, or "big brother" to the Mity-Mite. Work is presently underway to provide a back-pack, 5000 CFM tunnel flusher to accomplish this job.

Tunnel Exploration Kit

Work is being done at Natick Laboratories. Initial requirement established under ENSURE # 64. No development is envolved, only purchase of required components of the kit such as pistol, silencer, Miner's head lamp, etc. First kits are expected to be shipped to USARV in June 1968.

NOTES FOR MEETING OF INTERSERVICE COORDINATING GROUP FOR TUNNEL PROGRAM:
by MR. MARTIN DAMGAARD

Individual and General Equipment Office, Development Directorate, HQ, USAMC (AMCRD-J). Programs supervised include those in Natick Laboratories, for feeding, clothing and equipping the individual soldier, those in the Engineer Topographic Laboratories for field Army mapping and surveying, and those in MERDC for fortification, barriers, demolitions, camouflage and deception, POL distribution, air conditioning, mine warfare, physical security, and guerrilla warfare countermeasures. In the last category is Project 1J624101D166, for exploratory development of Guerrilla Countermeasure Techniques. Task 03 of that project is for Tunnel Detectors.

On 21 December 1966, DA validated ENSURE 144, which states a requirement for 10 detectors of a type being developed by LWL, for evaluation during combat operations. ENSURE 144 was expanded by DA to include the seismic sonar and UHF radar detectors being investigated by Mobility Equipment Research and Development Center (MERDC). Follow-on effort to this development is included in the DA Search & Destroy Program which contains a requirement to ruggedize and improve these MERDC systems after the initial evaluation in SEA.

The AMC objectives under the ENSURE are to develop man-portable equipment which will detect a vertical one-man hole with from ½ to 1 ft. of soil overburden, and tunnel runways with up to 20 ft. of overburden.

Two seismic sonar detectors, from a $250,000 contract for 10, were shipped to ACTIV on 22 Mar 1968, accompanied by a MERDC engineer. Six more will be ready for shipment this week. USARV advised last Monday that the services of the MERDC project engineer with this shipment, are not required. Two seismic detectors are to be retained by MERDC for evaluation and test back-up.

Two UHF soil penetrating detectors, to supplement the seismic devices, are due in from the contractor in May, and one or both will be shipped to VN in June.

Also, 8 tunnel inspection periscopes have been provided, and each seismic detector is accompanied by an engine powered augur for mechanical inspection.

To assist ACTIV in their evaluation, but primarily to gather fundamental environmental and geological data upon which to base subsequent development, AMC is supporting a visit to VN by a six-man technical team from the Waterways Experiment Station, expected to depart about 1 May for a six-week visit. $100,000 from the Search and Destroy Package have been programmed for this purpose.

Other effort to be funded from the Search and Destroy Package includes:

Improvement of the seismic and UHF models following VN and CONUS testing, and procurement of advanced models for test, with $260,000.

Feasibility study of tunnel effluent detection, using gas samples collected by the WES team ($60,000)

Development of a frequency translator for analysis of signal and echo noises ($50,000), and MERDC in-house effort, at $60,000.

Tunnel detection was not included in the AMC FY 69 or 70 budget due to lack of an approved requirement when the budgets were prepared, but is funded thereafter at the $100,000 level. The DA Search and Destroy package for FY 69 is expected to provide $500,000 for follow-on development.

USAMERDC TUNNEL DETECTION EFFORTS (U)

as reported by Mr. Manfred Gale

Meeting of Interservice Coordinating Group for Tunnel

3 April 1968
at
OCRD Highland Building

CONTENTS

SEISMIC TUNNEL DETECTOR (U)

1. (C) DESCRIPTION:

The seismic tunnel detector is an active sounding system for the detection and mapping of tunnels from the soil surface. It consists of three (3) basic components: (1) An electronics package including a cathode ray tube for signal display and a self contained power source; (2) a three KW peak electrical power transmitting transducer; and (3) a small receiving transducer. The electronics package weighs approximately 40 pounds and is carried and operated by one man. The transmitting transducer, equipped with interchangeable circular plate or spike coupler, weighs approximately 25 pounds. The receiving transducer including cable weighs less than one (1) pound. The electronics package and transducers are interconnected by 30 foot cables. During use the search operation is directed by the operator carrying the display unit. This operator observes the "A" scope type display for tunnel related reflections while the helper systematically probes the desired search area with the transducers. Headphones are provided so that the operator can also operate the system passively and listen for tunnel related activities.

2. (C) PERFORMANCE:

The seismic tunnel detector will produce distinguishable tunnel echoes from tunnels at depths up to 10 feet in consolidated sandy or sandy clay soils. The self-contained power source provides eight (8) hours of search operation, and an auxillary 16 pound power source provides an additional 16 hours of search operation. The time required for a two (2) man team to make a sounding is approximately 30 seconds. Soundings are made every three (3) feet along the surface. Soundings typically appear as indicated in this oscilloscope photograph.

The left and right oscillograms correspond to over-tunnel and off-tunnel soundings respectively. Note the signal at the left of the scope trace in both upper traces. This is electrical crosstalk in the system, and has no significance. The upper left trace consists of a direct transmission between transmitter and receiver followed by a tunnel echo. The lower left trace was taken from inside the tunnel and represents the one way propagation time. Note that the tunnel echo begins at twice the time of the in-tunnel trace. In the off-tunnel case the direct transmission typically are lower than over-tunnel, and the echo is absent.

3. (U) STATUS:

Two (2) ruggedized experimental units were shipped to ACTIV for testing and employment in Vietnam on 22 March 1968. Five (5) additional units will be available for shipping to ACTIV on 12 April 1968. The remaining units will undergo CONUS and SEA testing which will result in techniques for extending detection range and simplifying interpretation.

MERDC SEISMIC TUNNEL DETECTOR
TECHNICAL DATA

<u>TRANSMITTER</u>

POWER	3 KW P.E.P
PRF	0-20 PPS VARIABLE
PULSE WIDTH	1 MS

<u>RECEIVER</u>

BANDWIDTH (VARIABLE)	HP 200-2200 HZ
	LP 2000 - 4000 HZ
DISPLAY	"A" SCOPE

<u>POWER SUPPLY</u>

INTERNAL MERCURY -
8 HRS SEARCH

EXTERNAL RECHARGEABLE
16 HRS SEARCH

<u>PHYSICAL CHARACTERISTICS</u>

	TRANSMITTER	ELECTRONICS
WEIGHT	25 LB	40 LB
DIMENSIONS	3 IN. DIA X 28 INCHES LONG	6 X 9 X 18 INCHES

UHF TUNNEL DETECTOR (U)

1. (U) DESCRIPTION:

The electromagnetic tunnel detector is essentially a man-portable, short pulse radar designed for transmitting into the soil from a short distance above the surface. Due to the short pulse duration and wide electrical bandwidth, the detector is able to detect and resolve small targets near the detector. Target echoes are sampled and displayed on an "A" scope which indicates echo amplitude versus time. Provisions are also made for producing a permanent and continuous record of subsurface profile by recording echo strength versus depth versus surface position on the Z, Y, and X axes, respectively, of a chart recorder or storage oscilloscope. This display enhances the ability of an operator to interpret the echo information.

2. (U) PERFORMANCE:

The seismic and electromagnetic detectors are complementary in that the first works well in wet or dry consolidated media while the latter works well in unconsolidated but dry media. Also, the electromagnetic detector has an advantage over the seismic detector since it does not require direct contact with the soil. Consequently, the search rate for the electromagnetic detector is higher.

The electromagnetic tunnel detector is capable of detecting tunnels at depths up to 10 feet in dry sandy or sandy clay soils. A self-contained power source provides 10 hours of continuous operation. The weight of the entire tunnel detector is approximately 20 pounds. The search and mapping rate of the electromagnetic detector is relatively fast since contact with the soil is not required.

3. (U) STATUS:

Two (2) ruggedized experimental prototypes suitable for testing and employing in Vietnam are currently under development and will be available for CONUS testing in May of 1968. Advanced signal processing techniques for extending range and improving discrimination are under investigation and will be incorporated in advanced development prototypes.

MERDC UHF TUNNEL LOCATOR

TECHNICAL DATA

TRANSMITTER

POWER	100 WATTS P.E.P.
PRF	4.0 MHZ
PULSE WIDTH	5 n s (3 db)
RING DOWN RATE	>2.0 db/ns

RECEIVER

SAMPLING TECHNIQUE

A - SCOPE DISPLAY

ANTENNA

SINGLE TRANSMIT/RECEIV! ANTENNA LOADED RIDGED HORN
BANDWIDTH: 80-250 MHZ

POWER SUPPLY

BELT PACK BATTERIES
8 - 10 HRS

PHYSICAL CHARACTERISTICS

	ANTENNA	ELECTRONICS PACKAGE
WEIGHT	12 LB	15 LB
DIMENSIONS	20 X 20 X 20 INCH	6 X 8 X 15 INCH

TUNNEL VERIFICATION DRILL (U)

1. (~~C~~) DESCRIPTION:

The tunnel verification drill is a screw type, narrow gage, gasoline powered drill which is used to unmistakably verify the presence or absence of a suspected tunnel. The drill consists of a 4.5 horsepower, two (2) cycle engine; a speed reducing power take-off; three (3) five-foot sections of ½ inch hollow steel tubing; and the specially designed 3/4 inch drill bit. The power take-off operates at 90 rpm and has a through center drive mechanism which allows the entire 15 foot drill shaft to remain assembled during drilling operations without significant whipping of the shaft. A quick release mechanism is provided so that the two (2) man operating team can quickly engage or disengage the shaft in 2.5 foot increments along the shaft. The entire unit weighs approximately 50 pounds.

2. (~~C~~) PERFORMANCE:

The tunnel verification drill will penetrate most soils, including gravelly soils, at an average rate of two (2) inches per second. The three drill sections provide up to 15 feet of penetration. The bit compacts the soil so that no spoil is brought to the surface. Since the bit is larger than the shaft, the unit essentially free falls when the bit breaks through the roof of a tunnel, thus providing a positive indication of a cavity. The soil compacted by the bit makes a stable air shaft through which tunnel destroying or clearing agents can be fed.

3. (U) STATUS:

Ten (10) prototype models of the tunnel verification drill have been fabricated. Three (3) items were shipped to ACTIV for evaluation on 22 Mar 68. An additional 5 units will be available for shipping to the same group on 12 Apr 68. The remaining 2 units are being used as experimental models in CONUS and SEA tests in an effort to increase penetration rate and reduce weight.

MERDC HIGH SPEED TUNNEL VERIFICATION DRILL

BIT: SCREW TYPE WITH INJECTION AND RETRACTION TAPERS. MAXIMUM DIAMETER IS 3/4 INCH.

SHAFT: THREE HOLLOW MATING SECTIONS: EACH SECTION FIVE FEET LONG AND 1/2 INCH DIAMETER WITH FLATS EVERY 2.5 FEET.

POWER ADAPTOR: 90 RPM THROUGH CENTER FEED WITH QUICK CONNECT/DISCONNECT WHICH MATES WITH FLATS ON SHAFT.

POWER: TWO CYCLE, 4.5 HP GASOLINE ENGINE.

PENETRATION RATE: TWO INCHES PER SECOND NOMINAL.

UNINTERRUPTED PENETRATION DEPTH: 15 FEET

TOTAL WEIGHT: 50 POUNDS

INFRASONIC TO SONIC TRANSLATOR (U)

1. (U) DESCRIPTION:

The infrasonic to sonic translator is a compact, lightweight, low power all electronic device which converts subaudio signals to audio signals while maintaining the relative harmonic relationships of the original signals. Multiplication of the infrasonic spectrum is accomplished by separating the input spectrum into individual frequency components, electronically multiplying the frequency components; reinserting the amplitude components; and multiplexing the synthesized frequencies. The infrasonic to sonic translator allows a human operator to use his normal aural pattern recognition ability to analyze seismic infrasonic signals characteristic of tunnel digging and tunnel activities.

2. (C) PERFORMANCE:

The infrasonic to sonic translator has an input bandwidth of 5 to 50 Hz and an output bandwidth of 100 to 1000 Hz. The dynamic range of the unit is 60 db. The input impedance is switch selectable for operating with low impedance sensors such as velocity type geophones or high impedance sensors such as Piezoelectric element accelerometers.

3. (C) STATUS:

Two infrasonic to sonic translators are currently under development and will be available for field testing in September 1968.

MAGNETIC TUNNELLING DETECTOR (MTD) (C)

1. (C) <u>DESCRIPTION</u>. The MTD is an unmodified Magnetic Intrusion Detector (MAGID) which is used with either an MCID T-14 Annunciator or a Type "P" Annunciator. The Annunciator must be modified to accept a wire transmitted output alarm signal from the MAGID in order to provide aural and visual indications of detection. The MTD therefore consists of a MAGID, a modified Annunciator, and up to 2 miles of WD-1/TT wire as shown in Figure 1.

2. (C) <u>FUNCTION</u>. The MTD will detect the act of tunnelling provided the tunneller is using tools made of ferromagnetic material. In addition, the MTD will detect the passage of personnel through the tunnel provided the personnel are carrying or have ferromagnetic materials on their person. However, the detection range in the latter case may not be as great as that experienced due to active tunnelling.

3. (C) <u>OPERATION</u>. The MTD is buried perpendicular to the expected direction of tunnelling activity. It is recommended that 6 to 24 inch burial depth be used; however if the tactical situation prohibits burial, the MTD can be sandbagged on the ground surface. When the MTD is buried a false alarm rate of less than two per day can be expected in a quiescent area, occurring as one or two short audio tones and not as a prolonged sequence of tones. Sandbagging on the surface will result in a higher false alarm rate. Digging with a metallic tool will result in a prolonged sequence of short audio tones and corresponding counts at the annunciator. Continuing monitoring of the annunciator is not necessary, as the counter will store the indications of digging activity.

4. (C) <u>TUNNELLING TESTS</u>. This system was tested for detection of active tunnelling and passage of personnel through tunnels at Edgewood Arsenal 18 and 19 March 1968.

In the active tunnelling tests, it was determined that digging with a standard entrenching tool could be reliably detected over a 50 foot frontage to a depth of 11 feet. Digging with a bayonet could be detected over a 30 foot frontage to a depth of 11 feet. A one pound size Maxwell House coffee can was detected the same or better than the entrenching tool.

Passage of personnel through a tunnel at an 11 foot depth was detected over a 50 foot frontage when carrying a M1 rifle at 1.5 feet per second. When carrying a 45 cal. pistol or bayonet personnel were detected over a 30 foot frontage. The depth of the tunnels was 11 feet.''

Figure 2 shows the pattern of detection when digging on the surface with an entrenching tool. This pattern was confirmed in the tunnelling tests to a slant range of 15 feet.

An uninformed NCO was given the task of observing the annunciator readout and determining when tunnelling was taking place. He correctly assessed the tunnelling activity with the entrenching tool 100% of the time that tunnelling took place over the 50 foot frontage.

5. (~~C~~) STATUS. 40 MAGIDs with modified MCID T-14 or Type "P" Annunciators are currently available for deployment as MTD's.

Field Trip to Conduct an Evaluation and Data
Collection Program in Vietnam (U)

1. (Ø) The primary purpose of this program is:

a. Data collection in support of seismic and UHF tunnel detector developments and technical assistance in the evaluation of prototype equipments.

b. Collection of tunnel/environment air samples in support of the development of rapid search tunnel detectors.

A secondary purpose is to collect data on environmental factors related to the confidential project COFRAN. Inclosure 1 lists the various functions of the program, the measurements or samples to be taken, the equipment to be used and the most important parameters or relations to be derived from the measurements. A detailed "plan of operation" is in preparation and will be available at the time arrival of the WES team in Vietnam.

2. (Ø) To accomplish the various technical aspects of this program, a six-man multidiscipline team is required. (See Inclosure 2 for names and disciplines). This team will require six weeks in Vietnam beginning approximately 1 May 1968, and will visit tunnel sites in the five different physiographic regions delineated on the map (Inclosure 3), i.e., terraces near Cu Chi, coastal plains near Phouc Le, highland around Pleiku, narrow coastal plains near Quang Ngai, and the intermediate highlands near the demilitarized zone. It is realized that it may be impossible to visit all the specified areas, and other areas may have to be substituted for them.

3. (Ø) To obtain the data on all the items listed in Inclosure 1, the team would need access to each site for about three days. However, access to a tunnel site for only a few hours would be sufficient to obtain a considerable amount of useful data. The data collected in regard to certain munitions need not necessarily be related to actual tunnel sites at all, but should be collected in the five different physiographic regions.

4. (Ø) The Chief of Engineers, DA, has recommended that the team be assigned a central base from which to operate, such as the U. S. Army Engineer Command at Bien Hoa. At least 432 sq ft of office and laboratory space, billets and mess accommodations, and base transportation would be required. Access to a soil laboratory to obtain moisture content on about 100 soil samples would be desirable but not absolutely essential. Transportation support would be required for travel to and from the various regions, for travel on the base in the region visited, and for travel from the base to a study site. All the equipment used by the team can be contained in approximately 12 footlockers, four of which are required for the equipment needed to take data at a tunnel site.

5. (U) The WES sent a tunnel research team to Vietnam in February 1967. This team was sponsored by U. S. Army Materiel Command and the Advanced Research Projects Agency (ARPA), and its activities were coordinated by the ARPA R&D field unit in Saigon. The logistical support for the team was provided by the ARPA R&D field unit and the 25th Infantry Division. Several members of the 1967 team are also assigned to the currently proposed work as noted in Inclosure 2.

6. (C) The development of efficient, easily usable tunnel detection equipment is urgent and the problems encountered are very complex. To a large degree, the solutions to the problems require detailed knowledge of the enviornment in which the detection equipment will operate. Consequently, it is imperative that data concerning the seismic, E-M and trace gas properties of the soils of Vietnam be collected and analyzed. This proposed work will aid the Army's tunnel detector development program significantly. Early concurrence with this field trip as proposed by the Department of Army, and an appropriate address to which the necessary equipment may be shipped, has been requested from USARV. A separate request for theater clearance for the personnel involved will be made at a later date.

7. (U) The planned field trip will be coordinated with ACTIV which will be assisted in detector evaluation.

Collection of Data Related to Tunnel Detection in Vietnam

Function	Measurements or Sampling	Equipment	Derived Parameters*
Data collection in support of Seismic Tunnel Detector Development and technical assistance	Vertical propagation velocity Vertical attenuation Lateral attenuation Media backscatter	Prototype seismic tunnel detector, scope, camera, and adaptor	Short pulse dispersion Tunnel scattering efficiency
	Soil profile description Disturbed soil samples, by horizon, 0 to 10'	Sampler and soil containers	Particle content versus depth Moisture content versus depth (& as a function of rainfall) Organic matter content versus depth pH factor versus depth Metallic Oxide content versus depth Salts content versus depth Density versus depth
Data collection in support of UHF Tunnel Detector development	Vertical propagation velocity Vertical attenuation Lateral attenuation Media backscatter	Video pulser, antennas, power source, sampling oscilloscope	Short pulse dispersion Tunnel scattering efficiency Conductivity versus frequency Particle content versus depth
	Soil profile description Undisturbed soil samples, by horizon, 0 to 10'	Sampler and soil container	Moisture content versus depth (& as a function of rainfall) Organic matter content versus depth pH factor versus depth Metallic oxide content versus depth Salts content versus depth Density versus depth

*Computations and laboratory analysis (except moisture content) of samples will be done in the U.S.

Collection of Data Related to Tunnel Detection in Vietnam - Continued

Function	Measurements or Sampling	Equipment	Derived Parameters*
Collection of tunnel/ environment air samples	Air samples from unoccupied tunnel	Gas absorption bottles and pump	Spectrometric analysis of air sample from unoccupied tunnel
	Air samples from occupied tunnel		Spectrometric analysis of air sample from occupied tunnel
	Air samples from above disturbed earth in tunnel		Spectrometric analysis of air sample from above disturbed tunnel earth in tunnel vs time
	Air samples from atmosphere around tunnel		Spectrometric analysis of air sample from atmosphere around tunnel
	Air flow in unoccupied tunnel	Wind probe	Breathing rate of unoccupied tunnel
	Air flow in occupied tunnel		Breathing rate of occupied tunnel
	Air temperature from some points air samples are taken	Temperature sensor	
	Air humidity from some points air samples are taken	Humidity sensor	
Study of critical environmental factors affecting certain munitions	Ambient temperature	Temperature, humidity, wind, & solar radiation probes attached to portable battery operated recorder	Ambient temperature, vertical profiles vs time
	Ambient relative humidity		Ambient relative humidity, vertical profiles vs time
	Soil temperature		Soil temperature vs time
	Relative humidity near ground surface		Relative humidity near ground surface vs time
	Wind speed near ground surface		Wind speed near ground surface vs time
	Solar radiation near ground surface		Solar radiation near ground surface vs time

*Computations and laboratory analysis (except moisture content) of samples will be done in the U.S.

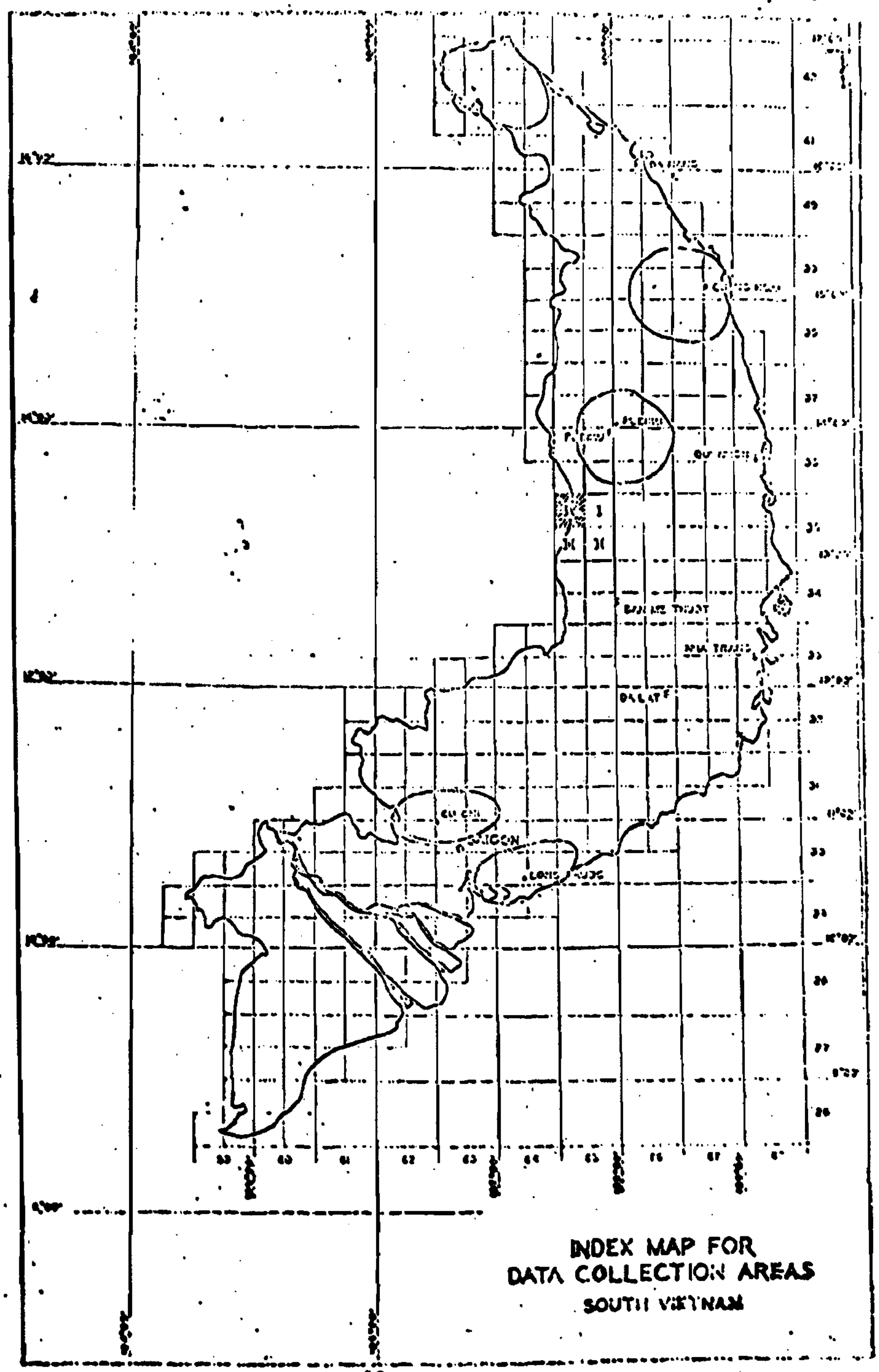
Personnel Assigned to the Vietnam Tunnel Research Team

Benn, B. O.*	GS-13	Supv Res Civil Engineer
Addor, E. E.*	GS-12	Research Botanist
Riley, R.E.	GS-09	Electronics Technician
Jetton, George H.	GS-06	Electronics Technician
Molthan, H.D.*	GS-11	Res Soil Scientist
Southwest Research Institute Representative		Electronic Engineer

Alternates

Davis, B.R.	GS-13	Supv Research Physicist
Grabau, W. E.	GS-14	Supv Research Geologist
Collins, J. G.	GS-11	Research Civil Engineer
Williamson, A.N.	CS-12	Research Physicist
Eckard, E. W.	PFC	CivilEngineer
Smith, P. A.	GS-11	Physicist
Rushing, W. N.*	GS-11	Research Botanist

*Members of 1967 Vietnam Tunnel Research Team.



INDEX MAP FOR
DATA COLLECTION AREAS
SOUTH VIETNAM

Incl 3

Tunnel Detection Efforts During the FY69-70 Period

Advanced development of the seismic and electromagnetic locators will continue through FY69 with emphasis on automatic signal processing to reduce the false signal rate and simplify the training required of the operator. These systems will reliably and accurately determine the location of tunnels in suspect areas. However, the requirement of point-by-point search does not render them suitable for the searching of extensive areas.

In the FY69-70 period the major portion of the effort will be directed toward the development of techniques suitable for rapid scanning from remote locations. Studies and evaluations will continue in the areas of trace gas effluent detection, electromagnetic scattering from tunnels and the ground surface, wave propagation annomalies, and soil disturbance measurement techniques such as argon detection and ecological effects. The evaluation of alternative approaches will be based on detection performance as well as on operational characteristics and cost effectiveness. The objective is to develop a practical system which is suitable for ground and airborne operation under a variety of tactical conditions.

DELIVERY SCHEDULES

SEISMIC TUNNEL DETECTORS

Two (2) items were shipped to ACTIV, Long Binh, on 22 Mar 68, escorted by an Electronic Engineer (Military).

Six (6) items will be shipped to ACTIV on 12 Apr 68.

Two (2) items will be shipped to Ft. Belvoir for testing on 15 Apr 68.

VERIFICATION DRILLS

Three (3) items were shipped to Long Binh on 22 Mar 68.

Five (5) items will be shipped to ACTIV on 15 Apr 68.

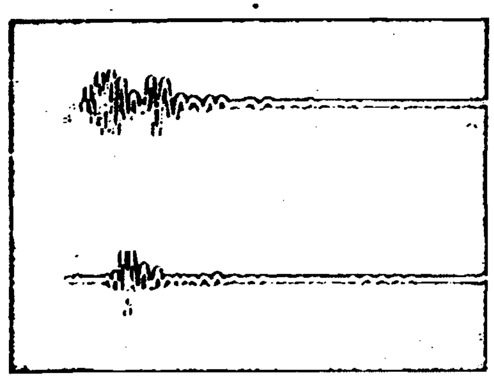
Two (2) items will be shipped to Ft. Belvoir for testing on 12 Apr 68.

ELECTROMAGNETIC TUNNEL DETECTORS

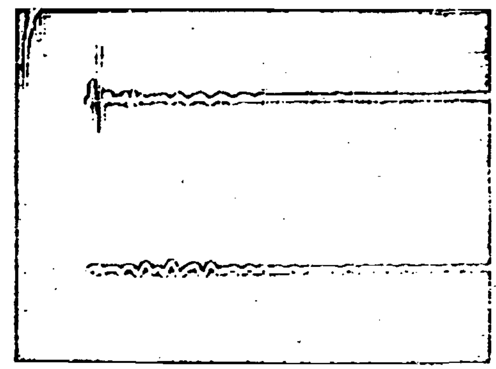
Currently under development with two (2) units to be delivered to Ft. Belvoir for testing on 31 May 68.

INSPECTION PERISCOPES

Eight (8) units were shipped to ACTIV on 16 Jan 68.



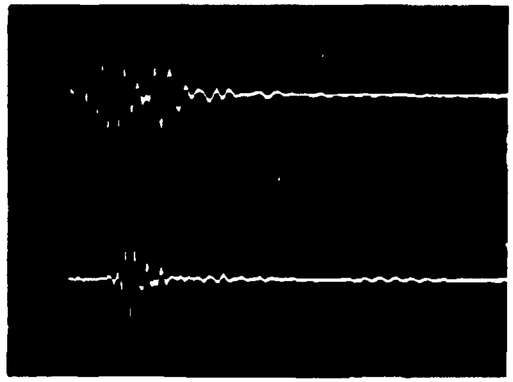
TOP—OVER TUNNEL 10 mv/div
BOTTOM—IN TUNNEL 20 mv/div
horizontal scale — all traces 5 ms/div

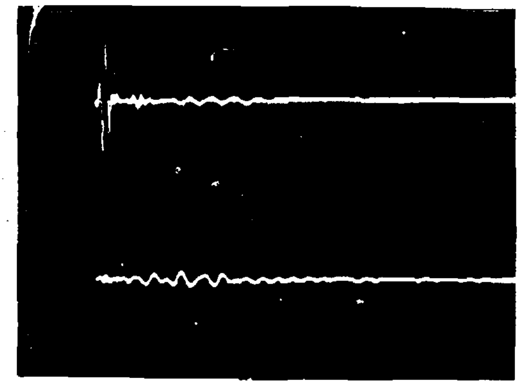


NOT OVER TUNNEL
both traces 10 mv/div

TYPICAL OSCILLOGRAMS FOR 12 INCH TRANSMITTER BASE
SAN ANTONIO, TEXAS

PROTOTYPE SEISMIC TUNNEL DETECTOR IN OPERATION

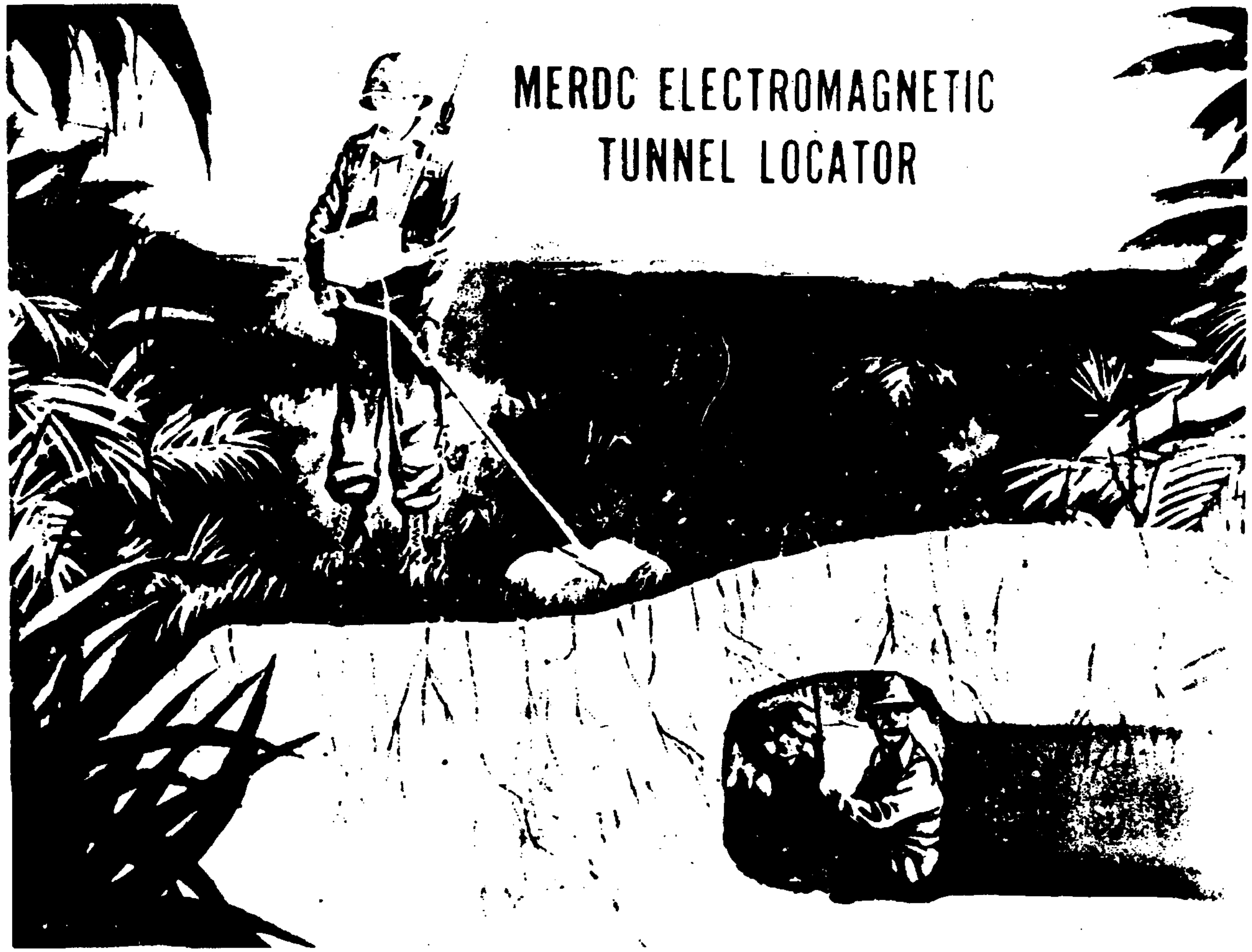




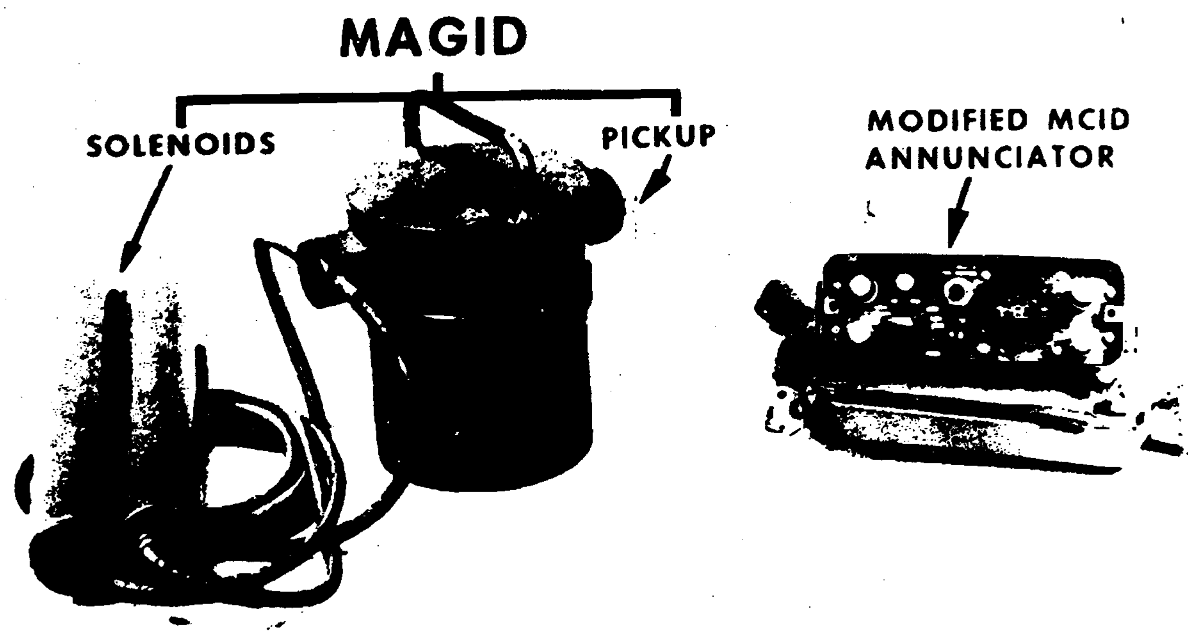
TOP—OVER TUNNEL 10 mv/div
BOTTOM—IN TUNNEL 20 mv/div
horizontal scale — all traces 5 ms/div

NOT OVER TUNNEL
both traces 10 mv/div

TYPICAL OSCILLOGRAMS FOR 12 INCH TRANSMITTER BASE
SAN ANTONIO, TEXAS

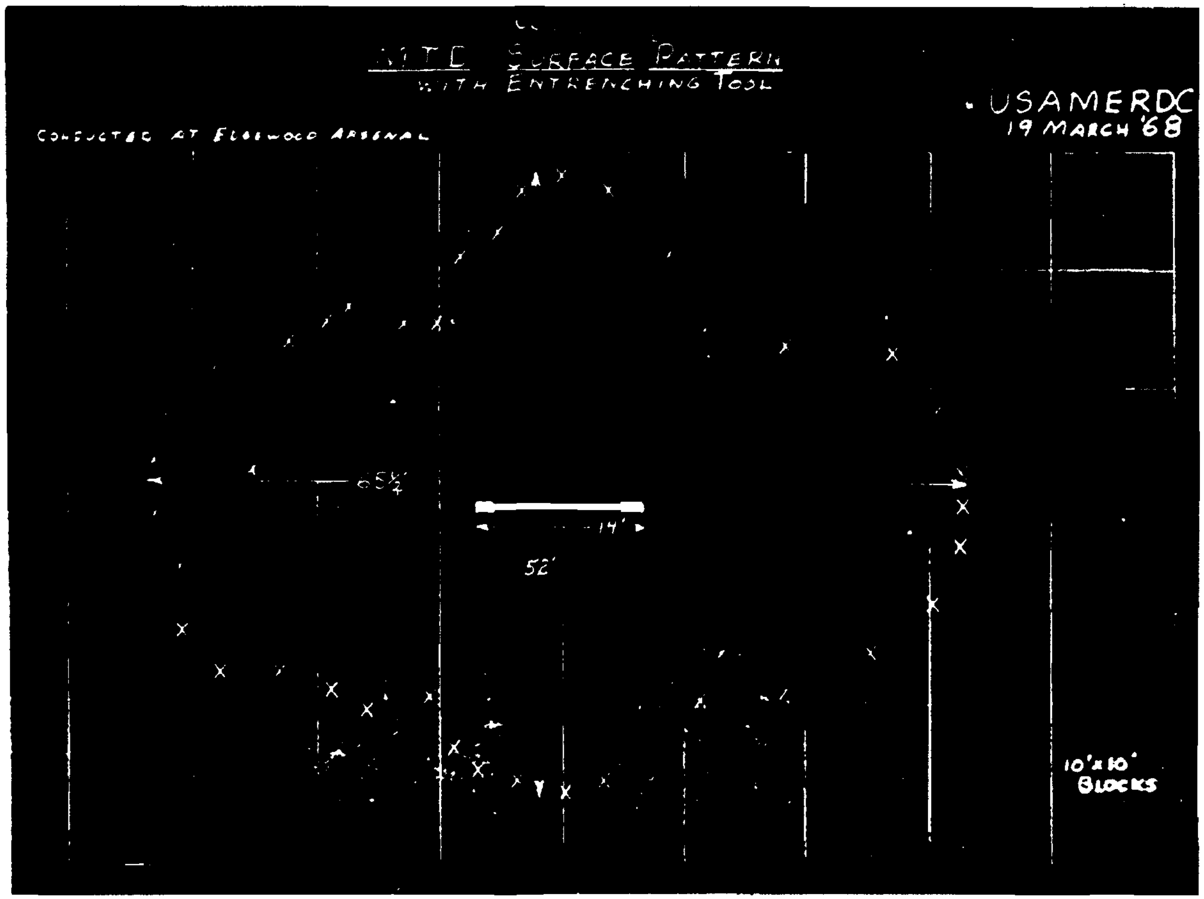

MERDC ELECTROMAGNETIC
TUNNEL LOCATOR

FAST SPEED NARROW GAGE DRILL IN OPERATION



MAGNETIC TUNNELLING DETECTOR (MTD)

~~CONFIDENTIAL~~



~~CONFIDENTIAL~~

US Army Limited War Laboratory's Tunnel Detection Program

LTC Robert J. Cottey

I am LTC Cottey from the U. S. Army Limited War Laboratory at Aberdeen Proving Ground, Maryland.

In his opening remarks, General Ostrom made the remark that, "the state-of-the-art for tunnel detection is a dog!". This remark is most apropos for a lead-in to my subject, since I will discuss the use of dogs for tunnel detection.

For over two years, the U.S. Army Limited War Laboratory has been involved in various detection programs involving dogs. By way of a prelude to our immediate subject, let me relate a brief summary of our off-leash scout dog program which was conducted in 1966 and 1967. German sheperd scout dogs were taught to range freely off-leash in front of a handler at distances of 100 to 200 meters. The dogs were taught to alert on humans and, once alerted, to sit. Affixed to a harness about the dog's neck was this radio transmitter. The transmitter is FM, crystal controlled, 46.85MC with a power output of approximately 450 milliwatts. In addition, the transmitter contains a motion sensor which senses the movement or non-movement of the dog. Total weight is approximately 18 ounces. The handler was equipped with this standard PRR-9 receiver. When the dog moved, a sinusoidal signal was received in the receiver by the handler. When the dog alerted and sat, the sinusoidal signal stopped. By this method, the handler was kept aware of the dog's movement while the dog was out of sight of the handler. If the dog alerted, the handler notified the patrol leader who then took appropriate action. During April and May of last year, four dog/handler teams were deployed to Vietnam for operational evaluation. The teams participated in combat patrols with the 1st Air Cavalry Division and the 1st Infantry Division. Results of this evaluation were generally favorable. As a result of the evaluation, several actions have taken place. First, CONARC has directed that off-leash training be included in the scout dog training program. To this end, LWL is assisting CONARC in the procurement of the radio transmitters and receivers required for the training.

A second result has been the initiation of a two-pronged follow-on scout dog program by LWL. A contract was let to Behavior Systems, Inc., in January of this year to conduct a 12-month program. Initially, 12 dogs will be used in a feasibility to determine the feasibility of training dogs to search for, detect, and respond to camouflaged, as well as uncamouflaged, tunnel openings and openings into other ground cavities. One multiple opening tunnel comparable to a typical VC tunnel and other excavations of varying dimensions and configurations will be used for training purposes. The dogs will be trained to make a specific response in immediate proximity to the tunnel openings while working both on and off leash. Our current schedule calls for a demonstration of the feasibility of the concept at the end of the sixth month of the contract which will be mid-July. If feasibility is demonstrated, two squads of the 60th Infantry Platoon, Scout Dog will be trained for tunnel detection. This Platoon has been activated by CONARC to specifically support our program. This training will be conducted at Fort Gordon, Georgia, site of the new CONARC Combat Tracker Tream Training Program. Following a six months training program at Fort Gordon, the Squads will be deployed to Vietnam in January 1969 for operational evaluation.

I mentioned that our program is two-pronged. In addition to the tunnel program, we have an identical program to train two squads of scout dogs to detect mines, booby-traps and trip wires. The schedule for these squads is identical to that which I have just discussed.

Gentlemen, that completes my portion of LWL's briefing. May I answer any questions?

TUNNEL DETECTION USING MAGNETOMETERS

Mr. Jacob Wenig

The USALWL has had an early and continued awareness of the tunnel detection proglem. A USALWL Liaison Officer is always in VN and maintains an open technical and military operations "ear" for problem areas and military requirements.

It did not take an elaborate analysis nor lengthy voluminous studies to determine that tunnels as used by the VC were powerful weapons that required actions to counter their effectiveness. We, therefore, addressed ourselves to an area where we could apply technical input as well as produce hardware to be used by the men in the field. This was tunnel detection.

We examined potential technical approaches to tunnel detection--seismic, infrared, radar, gravimetric, magnetic, etc. Against the techniques considered, we weighed the military factors of employment, speed of search, tactics, readout or display, as well as size and weight complexity of the equipment. With these in mind, we concluded that the most promising tunnel signature was its magnetic contrast. Some characteristics of tunnels reflect themselves as indirect measurable quantities; others require elaborate equipment, and some are too time consuming to be operationally suitable. The magnetic signature was felt to be operationally useful if a suitable device were available.

Let us look at tunnels from a magnetic detection point of view. Basically tunnels are made by either boring in the earth or by "trench and fill." The trench and fill method produces a disturbed overburden, which is a large magnetic anomaly as compared to bored tunnels. Bored tunnels may be constructed in many ways. They may be produced by starting at a stream bank, from a hut, or by starting in a jungle growth area. However, in both kinds of tunnels, one common fact came to light. Tunnels usually run in straight line segments. Digging tunnels is hard work. Apparently the legs of the tunnels are run for a distance, air shafts made and then the direction continued or rerouted. It's possible that the air shafts are used to sight tunnel directions. Besides running in straight lines, when tunnels change direction, they usually do so with a rather sharp change in angle. With the knowledge that tunnels generally run in straight lines, we had available another signature or characteristic that was amenable to detection.

In order to use magnetic detection techniques, one must measure the contrast of the tunnel--the change in the earth's magnetic field produced by the tunnel. Basically there are two forms of magnetic measurement tools available. One is a component field device and the other is a total field device. Component field instruments are not suitable for tunnel detection because they are inherently orientation sensitive in a single sensor configuration and lack sufficient sensitivity in the differential configuration. However, a total field device would allow for continuous search with a minimum of adjustments and interpretation if one keeps in mind that the anomaly we are looking for is a straight line disturbance.

Tests were conducted using a rented Rubidium Vapor Magnetometer manufactured by the Varian Co. This was the same unit used over a long period to locate the lost city of Sybaris in Italy.[1] Although there were problems in repairing the unit (one shouldn't run an experiment without spares), the results confirmed the premise that the straight line correlation of the magnetic signature of tunnels is a technically valid approach. Reference 2 reports the data, analysis and results of this effort.

After this exploratory phase, work was initiated to quantify the process of magnetic detection of tunnels. The results are given in ref. 3. Also at this time a magnetometer was sent to Vietnam to get some field feedback to aid in the development of a militarily hardened device. The unit was used by an NCO who had only minimal training on the device. After a combat mission, the operator traced 200 feet of a tunnel about 5 feet deep, using a discovered opening as a starting point.

Three other legs of a tunnel complex were later detected by this instrument. Unfortunately at a later secure site, where known tunnels existed, the operator could not positively detect or trace them. It was inferred that the soil was magnetically bland. It must be mentioned that the preceding tests were performed with the magnetometer in the readout mode. An audio tone was presented to the operator to indicate the magnitude of the anomaly. This readout had only moderate resolution and sensitivity and since then has been redesigned and improved. In more recent tests on tunnels at Edgewood Arsenal, the improved readout was used to trace tunnels and performed well.

An additional feature when using the magnetometer and the improved audio readout mode is an ability to determine the "extent" of an anomaly so that search speed is not reduced due to the presence of surface ferrous objects such as shrapnel or other "point" disturbances. For example, when swinging or passing the staff of the magnetometer over a piece of shrapnel, one can discern the rapid change of tone due to this small (although strong) magnetic source. When over a tunnel, the audio tone indicative of this large anomaly is proportionately present over a longer arc. In addition, we are operating in a physical sensing area where magnetic field strength is proportional to the reciprocal of the cube root of the distance. A tunnel may be well below the earth's surface. A "false alarm" point source object is usually at or near the surface. By raising the sensor staff from a height near the ground as well as swinging it in an arc, the signal strength due to the surface point source anomaly can be considerably reduced and by wavelength determination or discrimination, judged to be what it is--a small local disturbance. The tunnel signal, however, is not reduced significantly. Due to its depth, the distance between tunnel and sensor is not changed markedly when the sensor is raised.

The present status of the USALWL program is that a follow-on contract was awarded to Varian Associates on 9 April 1968 to develop and fabricate 12 improved differential magnetometer systems. The improvements will enable the systems to withstand the RVN environment. The systems will be available for RVN test and evaluation in the 2nd Qtr FY 69.

References:

1. "The Rubidium Magnetometer in Archaeological Exploration," Sheldon Breiner, Reprinted from Science, 8 October 1965, Vol. 150, No. 3693, p. 185-193.

2. Detection of Tunnels, Contract No. DA-18-001-AMC-896(X) by Westinghouse Electric Corp. for USALWL, 15 March 1966.

3. "The Tunnel Problem," LTC Henry F. Magill, OCRD, Dept. of Army (not dated).

Participation of the Waterways Experiment Station in the

U. S. Army Tunnel Detection Program

W. E. Grabau and B. O. Benn

The U. S. Army Engineer Waterways Experiment Station (WES) is not directly involved in the development of tunnel detection systems; instead, it regards its functions as one of providing field support for the acquisition of environmental data to those agencies specifically charged with the development of such systems. To this end, the WES conducted a field program in Vietnam during March and April 1967 with the objective of obtaining reliable data on the nature of Viet Cong tunnel complexes, and on the environments in which tunnels occur. The data collected during this effort have been published in "Environmental Characteristics of Tunnels in South Vietnam," by E. E. Addor, Miscellaneous Paper No. 4-919, USAEWES, Aug 1967. The information collected included data on soil morphology and classification, soil moisture and density, soil strength, seismic wave velocity, seismic wave attenuation characteristics, electrical conductivity of soils, atmospheric temperatures both inside and outside tunnels, humidity both inside and outside, vegetation taxonomy and structure in the vicinity of tunnels, and details of tunnel configurations.

Because the data described above had been collected only at a very few sites, and during the dry season, the WES was by no means confident that the presented data were representative of tunnel environments. Accordingly, the WES recommended that a team be returned to Vietnam to obtain needed environmental data on tunnel complexes and tunnel environments in other places, and at other seasons, especially the rainy season.

Much of the instrumentation carried by the 1967 field team was new and, even though it had been tested in the U. S., it was found to be inadequate in the South Vietnam environments. Accordingly, the WES also recommended that instrumentation be specifically designed for use in Southeast Asia.

The WES was also aware that the reliability of some of the data, notably those involving the electrical and seismic properties of the soil, left much to be desired. In view of this, it was suggested that those laboratories which were engaged in the development of tunnel detectors should carefully specify their data requirements for any subsequent data collection effort. Ideally, such laboratories should design and construct the test instruments, and specify in detail the procedures for using them in the field.

In view of the practical experience in Vietnam gained during the 1967 field effort, it was suggested that the WES would be a logical choice to conduct a follow-on effort to obtain all of those background data required for analytical sensor design. The WES could field such a team on about two months notice.

During the exploration of the Viet Cong tunnels during the 1967 field exercise, the WES personnel found that the problem of mapping out the planimetry and configurations of the tunnels was made almost impossible by the lack of communication between the tunnel explorer and his associates on the surface. Carrying a field telephone proved to be impractical because the wire could not be dragged around more than two or three bends without fouling. Theory suggested that standard citizen's band radio wavelengths would penetrate the overburden, which was usually less than 2 m. The team had taken two sets of cheap commerical walkie-talkie radios to Vietnam, to use in the event that it became necessary to talk among members of a survey team on the surface. The radios were found to provide adequate communication from inside the tunnels. Further, a procedure for locating the position of the tunnel explorer by measuring the field strength of the signal from the radio in the tunnel was developed, which allowed the team to map the planimetry of the tunnel complex much more rapidly than had previously been possible.

Upon return of the field team to the U. S., a more refined, sturdier, and smaller version of the "tunnel rat locator" was developed in the WES laboratories for use by WES personnel in any subsequent effort in Vietnam. The cost of producing one tunnel rat locator system in the WES shops is about $300.

The WES has a continuing AMC-sponsored research program in the area of remote or noncontact sensing. One device which is under development is an airborne radio system which will theoretically detect subsurface nonhomogeneties at depths of up to several meters. The original purpose was to detect soil stratifications, depth to bedrock or a water table, and so on by an airborne detection system. It is obvious that the device is potentially a tunnel detector, since a tunnel is also a nonhomogeneity in the soil. The WES has evaluated the system as a tunnel detector, and the current status has been reported in ~~SECRET~~ report "Feasibility Study of the Use of UHF Radio Imaging Techniques for the Detection of Tunnels," by H. J. Nikodem, Technical Report No. 3-769. Even if the system proves to be practical, it will take a considerable period (a year or more) to produce even an experimental prototype.

The Nuclear Weapons Effects Division, WES, has been working for some time on a project in tunnel destruction sponsored by Picatinny Arsenal. The WES role in this effort is to develop an analytical model which will define the conditions required to destroy tunnels with explosives. A series of scale-model experiments has been conducted, and some progress has been made toward the objective of the program. However, the consensus is that a reliable and general analytical model cannot be developed with the funds available.

In conclusion, and based on the assumption that the WES will send another field team to Vietnam to obtain more reliable and more geographically diverse data on tunnels and tunnel environments, it is strongly urged that:

a. Those laboratories concerned with the development of tunnel detectors define their data requirements as quickly as possible and send the specifications to the WES. This will assist the WES in designing its field activities.

b. Those laboratories which have data requirements involving special instrumentation should develop those instruments (hopefully in coordination with the WES, to insure that the instruments are practical for use in the field), so that they can be taken to Vietnam by the field team.

c. Those laboratories which have data requirements demanding special collection procedures should consider the immediate training of the WES field personnel, to insure that the procedures are properly followed.

AIR FORCE TUNNEL DETECTION REQUIREMENTS AND PROGRAMS - SEAOR #101 (U)

Major Clint Houston

GENERAL

(U) The SEAOR (Southeast Asia Operational Requirement) is an Air Force document that identifies and expresses operational deficiencies or needs of Southeast Asia combat forces and seeks relatively near-term solutions. Seventh Air Force which initiates the SEAOR's is responsible for the conduct of tactical air operations in Southeast Asia as directed. The responsibility extends to the establishment and maintenance of air base perimeter security--hence, the interest in intrusion by tunneling.

SEAOAR #101

(C) SEAOR #101 establishes the requirement in the Air Force "for a reliable, positive means of discovering the presence of tunnels and tunneling activity under the perimeter of Tan Son Nhut Air Base, Republic of Vietnam." The perimeter is nearly 11 miles in length. General system characteristics were defined:

a. Detect both tunnels in-being and the process of active tunneling.
b. For active tunneling, transmit an alarm to a central control point and provide location accuracy to ± 15 feet.
c. For existing tunnels, permit tunnel mapping.
d. Operate with high reliability in both wet and dry seasons.
e. Recognize and reject noise that would degrade system capability (e.g. disturbances caused by vehicle traffic, bombing, artillery, air traffic, thunderstorms, lightning, radio frequency interference (RFI),power generating equipment and like causes which could generate false alarms).
f. Be installed and operated in interrupted segments, in order to exclude normal access road areas.

(C) Air Force Cambridge Research Laboratories (AFCRL) was designated Office of Prime Responsibility. Our basic Best Preliminary Estimate (BPE) was submitted in May 1967 and modified by addenda, one each in June and July, as additional technical information became available. Let me state at this time that Air Force has not funded an R&D tunnel detection program under SEAOR #101 in whole or in part as recommended and outlined in the BPE + addenda. Two factors have operated against the initiation of this program:

a. The near-term solution criteria of a SEAOR could not be met.
b. Greater urgency has been placed on other requirements.

(C) Time has had its impact upon the total recommendations and has reduced their number. I will briefly outline those techniques or systems recommended for consideration and support and still considered relevant.

a. The briefing by Manfred Gale from the Intrusion Detection and Sensor Laboratory of the Mobility Equipment Research and Development Center amply covered their seismic Sonar development, one of the seismic systems incorporated in our recommendations.

A second seismic development of theirs, the Tunneling Detector, was also recommended. This system consists of an array of 4-5 geophones, an electronics package (power pack, amplifier, and logic element), an enunciator with a triple display (audio and light alarm + digital readout indicating tunneling intensity). The seismic information is transmitted by hardwire.

The Tunneling Detector would fulfill, in part, requirements set by the SEAOR to detect active tunneling but would not provide the desired location accuracy (± 15 feet). Instead, it would protect an area approximately 100m X 40m. More precise location could then be provided by a mobile system such as their seismic Sonar.

If employed, adaptation to Tan Son Nhut would undoubtedly require some modification of the system.

b. The SEAOR also contained recommendations regarding two radar type systems. The first was incorporated at the suggestion of Rome Air Development Center (RADC) and will be described in detail by Robert Purpura, an RADC representative.

The second, an MIT Lincoln Laboratory development, employs a wide bandwidth, 50 to 150 MHz, generated by a DC transmitted pulse 3 to 5 nano seconds in duration. A comprehensive description to this system will be presented by either Bob Purpura or Charles Ravitzki (ARRA). Funds internal to RADC were provided for the first system. Funding for the second may result for its incorporation as part of the Air Force Integrated Air Base Defense Program.

VARIAN MAGNETOMETER

(C) Separate from and prior to the EPE, Air Force purchased two Varian Portable Search Magnetometers to be evaluated as tunnel detection devices. A report summarizing the test results was recently completed. Both Air Force and Army units participated in the evaluation. An audio readout was used for all tests.

a. Army participated in tests in CONUS and conducted field tests at Cu Chi, Di An, and Katum in April 1967 in Vietnam.

b. 7th Air Force Security Police tests at 5 locations: Tan Son Nhut, Bien Hoa, Binh Thuy, Phan Rang, and Phu Cat ending in July 1967.

c. Joint System Commsnd LO-7th AF (IGS) tests at Binh Thuy and west of Tan Son Nhut in October and November 1967.

The report concluded:

> "All of the tests indicate that the instrument can detect tunnels only under certain conditions not common to the most common combat problems. None of the reports indicates that operators have sufficient confidence in the instrument to depend on it........ It is clear that the instrument is entirely inadequate for use in Vietnam to satisfy the requirements of SEAOR #101."

(C) Review of the results of the major tests are informative:

(1) CONUS True tunnels and shored tunnels with disturbed overburden. Tunnel diameter: 1-2 m. Depth: 1-10 m. True tunnels were not detected. Shored tunnels were detected.

(2) Cu Chi and Di An Tunnel diameter: 1 m. Depth: 1.5 m. No detection or tracing of known tunnels occurred at Cu Chi; Di Am, no detection occurred. At both locations soil appeared to have low magnetic susceptibility.

(3) Katum Tunnel diameter: 1 m. Depth: 1.5-2 m. Tunnel detected. Traced easily from entrance. More difficult to map by crossing. Lateritic content of soil high.

(4) Tan Son Nhut Tunnel opening diameter: 2 feet. Depth: 2 feet. Tunnels - not detected. Lateritic content of soil - low.

(5) Binh Thuy Tunnel dimensions not provided. Lateritic content of soil - none. Known tunnels were not detected.

The report also discussed operator dissatisfaction with equipment handling, inconvient assembly, excessive warm-up period, signal read-out, and false alarm rate.

ROME AIR DEVELOPMENT CENTER TUNNEL DETECTION (U)
Mr. Robert Purpura

1. (U) RADC has developed, under contract with A.I.L. at a cost of $50,000, an extremely simple C. W. tunnel detector. This device operates in the 90 MHz region at a power level of less than 100 milliwatts and is capable of a 5 to 1 signal to noise ratio on a tunnel four (4) feet deep and three (3) feet in diameter. The objective was to prove the feasibility of the C. W. approach prior to any attempts to perfect the antenna or display. At present, the equipment is in breadboard form and the antenna has to be in contact with the ground in order to perform detection. RADC is now proposing to continue this development on the antenna which would permit operation when it is mounted above the ground. Due to lack of funds to contunue the basic development on the antenna, RADC*is unable to continue this effort. Funds in the order of $25,000 are required. It is felt that if the antenna was perfected, then, it would be possible to build a hand held tunnel detector similar to a mine detector.

2. (U) RADC is also working with Lincoln Labs where this Center has generated an RFP (Request For Proposal) based on a lightweighted version of Lincoln's pulsed tunnel detector. This equipment will be reconfigured to hold its weight under 125 pounds, prime power under 250 watts and to make it suitable for the SEA environment. The equipment will be vehicle mounted, including the antenna, and the antenna will be capable of being removed from the vehicle to facilitate searching rough terrain. RADC has requested, but not received, $150,000 to accomplish this work. (Two models would be produced in six (6) months).

3. (U) RADC has chosen to base its RFP for a field model tunnel detector on the Lincoln design because this is more advanced in its development at this time, than the RADC/AIL equipment and would lend itself to a field model version with a minimum of risk.

4. (U) This manuscript is classified CONFIDENTIAL because it reveals performance capabilities and parameters of classified items.

*RADC - Rome Air Development Center, Rome, New York

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~~DECLASSIFIED AFTER 12 YEARS~~
~~DOD DIR 5200.10~~

U.S. Marine Corps: Tunnel Requirements

LTC Harlan Trent

General Ostrom, Gentlemen:

This portion of the presentation is to present the Marine Corps tunnel requirements and I suppose the best way to lead off is to say that we have no stated requirements. I suppose what I've said is the Marine Corps doesn't have any requirements for tunnel detectors. That is not exactly true. Our rationale for no stated requirements is the fact that we view a tunnel as a fortification, a package, in that vein. The difference of course, which has been brought out by the previous speakers, is the question of how do you detect a fortification that is underground. So our interest here is how do you detect the tunnel, the underground fortification.

Once it is detected then we simply turn it over to our Engineer Combat Service Support personnel, in the form of Major John McLean and say, well, we've done our part; you take care of the rest of it. Its all very simple and we simply move on.

I was interested to note this morning that one of the briefings mentioned the detection of tunnels by looking for straight line anomalies. We understand the rule about the same way--that is, that nature abhors a straight line and this can lead to the detection of your tunnel. Now we, like the Army, have analyzed what type of environment that we are going to be detecting tunnels in in the future. As just a reiteration, probably something all of you have heard before, we view the future tunnel environment as one which probably deals with wars of national liberation--wherein the U. S. will have dominance of the air and probably the sea lanes. When we go into an area to counter our dominance in the air and the sea and our ability to move mass groups of men and equipment over the terrain, the enemy will counter by going into a tunnel. In other words, he'll either depend upon mobility to move faster than we can in another environment or he's just going to simply go underground. So we see then that there is going to be a real need for these particular devices that you gentlemen are discussing here today.

Now while we have no stated requirements, there are certain things that we look for in the particular devices that you are developing, and in part they have been stated previously. So I am just going to reiterate some of them.

We like to be able to take this thing with us in the field. I am also reminded that in our R&D effort we are finding more and more that we are developing a myriad of little two and one-half pound boxes. We feel that somewhere in the mid-range time frame that we will be able to provide enough 2-1/2 pound objects to probably effectively immobilize our combat personnel.

Another requirement, if you will, characteristic, is that it is going to have to be used in all the world areas. And a thought crossed my mind here--how do you detect a tunnel in the snow, for instance.

When you get to working the devices, it's got to be simple. Remember, gentlemen, you are going to have our mental group 3's and above operating these things. It's got to be quick. We've pointed this out already.

But basically what do we mean by quick? Well, generally speaking for our particular requirements, it's thinking of the rate of the walking man to traverse what is known as type 2 terrain; we have to have type 2 optimum mobility.

It should, of course, obviously work under combat conditions in the field, but it is not a simple factor. Remember that most of our people probably are operating this under an environment that, to say the least, is extreme--and if you are standing up and moving across a piece of open terrain and there is a sniper out at 700 meters firing at you, he can probably ruin your afternoon for you. So we have to have some way of protecting an individual either by rearrangement of the equipment or some other method. I am really posing a problem more than trying to make a solution.

Another area that we may get involved in is how do you detect "tunnels in an urban environment"? We may very well get into an urban crisis--not necessarily outside the United States either. The point is that our tunnel requirements should span the whole spectrum, offensive and defensive. Now the Air Force spoke, I think, quite cogently about their defensive requirements.

And those are some of the--while I didn't call them requirements, I think they are characteristics, that we are looking into. We're asking you folks to look out for us because we are really not a laboratory operation of our own. We are kind of customers for you folks. We look at what you have and we say we'd like one of those and one of those and we buy them, take them and put them in the field--that is COL Ratcliff buys them for us.

At this point in the presentation I would have liked to have presented one of our main customer-users of your equipment, but because of the plans for the later DCPG briefing, I think I would prefer MAJ Lee talk to you later.

I've talked here for about 7 minutes and really all I've done is literally pose some questions and not really stated a Marine Corps' position other than we need something--and what we are really doing, gentlemen, is looking at your efforts and gleaning from what you are presenting here today and we will take back and try to get the best of those that tend to meet our requirements.

Q. Would you comment on the Marine Corps use of dowsing rods over there?

A. Well, it's interesting you should ask that question; I really don't know how to answer you because the dowsing program is not in my office. There is again no stated Marine Corps position on dowsing, but we actually do have people in the field that are using it. I suppose what we really come down to is this. We take the pragmatic approach. We don't know why dowsing works. We have evidence from our people in the field that some things are found some of the time by some of the people using these dowsing techniques. Therefore, we said: "Well, if you want to use this go ahead." We have people, individuals on both the east coast and west coast of the United States who are conducting small training programs in using what amounts to bent coat hangars. And I have had a literature search made and I have quite a bit of documentation telling me both why it can work and why it can't work.

At the present time, the TV school at Monterey has done a small study on it, using some people going through the school, and found non-conclusive results. However, the professor who assigned the topic wrote a letter the other day and indicated that he has now developed an interest in it and is going down to a Chapter in the American Society of Dowsers, down in Glendale California, and is going to talk to some "real dowsers" and find out what they know about it.

This thing has a considerable emotional impact. I find that people either believe it or they don't, and they polarize--they really believe it or they really don't believe it. I don't know. I think the pragmatic approach probably is the best one to satisfy me at this time. We are getting some results; we don't know why. We are not getting them by the scientific method, that is you can't take them as a universal reaction. Some people get no reaction, some people get some; some people get more than others. I've heard the statement made that it's probably a talent like throwing football. Some can and some can't.

I might add the best theory that I have heard on the subject was one proposed by LT Berryhill, a geologist at Belvoir. His theory is the one that when people ask me what do you think about it, I say this is the one that sounds best to me. He said the body is a walking thermometer and that there are tiny celia in the inner ear, that controls the balance and what it is doing is measuring the density of the air that you pass over. What this tiny celia does is telling you constantly that there is a change in density. When you hold a pair of dowsing rods in your hand, what you are doing is you are creating a tension here--you are actually listening to the celia in your ear a little more intensly. You are focusing your attention. And he says that he thinks this is why actually the human body detects. It is an anomaly. But I reasonably think that some people get responses and others don't.

Q. (Ravitsky) Do you want me to express my view on ARPA's view on dowsers? Let me first say that as a physicist I do not like the celia explanation. What the inner ear does is measure down, to a certain precision; the anomaly due to a tunnel in this case water 60 feet down, or a tunnel 20 feet down, is smaller than the ear, than the human can detect as a perturbation.

Response. (LTC Trent) I defer to that, simply because I do not know any better. And as I say this is the best explanation that I have heard. We do not know. We really don't.

Q. (Gen Ostrom) At this point has the Naval Research Office done anything about joining forces with you to look into this on a piece step program, first selecting and then training?

A. (LTC Trent) They have not. We queried them a year ago as to data on the subject and they indicated at that time they had no data.

Comment. (Gen Ostrom) I called ADM Owen two or three weeks ago and ask[illegible] him to follow up a little more closely on it. He indicated he would follow it some more.

A. (LTC Trent) This is a new, evidently a new ballgame, General, and evidently I had better follow up on it, because as I say our information is over a year ago.

Comment. (Ravitsky) There has been some interest in this raised recently by Hansen Baldwin who visited Camp Pendleton and he was told that the Marines are teaching groups of recruits to find tunnels using dowsing rods. I called Marine Corps Headquarters, probably spoke to somebody in your shop, and was told that there is indeed a Marine Corps Major at Camp Pendleton who knows where the tunnels are and who conducts demonstrastions to show that when he controls the dowsing rod he can find the tunnel. And this builds up the self-confidence of the Marines who later go out and try to use the dowsing rod.

Response. (LTC Trent) It is really a command level operation in which we do not say it should be done or we do not say it should not be done, and then they go ahead and do it.

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The ARPA Tunnel Detection Program

Charles Ravitsky

GEN Ostrom, Gentlemen:

I think most of you have received the very fine summary of the work done on tunnel detection thus far, prepared by Dr. Bryant. A sentence in that summary states: "Research on tunnel detection was initiated in June 1964 by ARPA" with a contract with the Advanced Technology Corporation of Timonium, Maryland. While Dr. Bryant is correct in saying that ARPA did let a contract at that time, research on tunnels actually dates back to Biblical times. Joshua used them in the battle for Jericho.

ARPA has done appreciable amount of work in tunnel detection. Stimulated by the problems in Vietnam, in May 1966 we started a cooperative program there with the Australians, who investigated methods of improving the rate at which tunnels could be located and how they could be annihilated. This was part of a five-phase program to (1) devise methods for determining areas where tunnels might exist; (2) determine where tunnels actually exist; (3) devise means for outlining tunnels of a complex from the surface of the earth; (4) devise means for flushing tunnels to get the inhabitants out; and (5) devise means for denying further use of these tunnel complexes. We made analyses of the location of the known Vietcong tunnel installations in Vietnam to try to determine whether there was a systemic pattern in the location of tunnels, and we conducted an investigation into the geological and hydrological characteristics of the ground in which tunnels had been built.

Some of the Vietcong tunnels are over 20 years old. They probably had their genesis in the French-Indo China War. Since then, the Vietcong havebeen using tunnels to prepare set-piece battle fields, where they are safe. The VC knew where their tunnels were and, when attacked and pursued, they retired to their tunnels and destroyed the attackers.

As a specific illustration, the Australian Army knew that a tunnel complex is located in a particular wooded area. A battalion was sent in to find the tunnel, destroy the inhabitants, and disable the tunnel. The soldiers formed a line, and went into the woods looking for a tunnel entrance. They found the tunnel when one of the men was shot in the back. He had walked right past a tunnel bunker without seeing it. The Australians stayed in the woods for about a week and gradually located more and more of the tunnel complex. They never found the entire complex, and finally left.

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The results of the study that ARPA and the Australians ran indicate that there are over 5000 tunnel complexes in South Vietnam. The majority are thought to be preplanned battlefields. We have examined the areas in Vietnam where there are likely to be tunnel complexes and we plotted all the known tunnels on a map of Vietnam. In general, they are within a one day's walk from a major inhabitated area.

We also had a geologist go into Vietnam to conduct a study to determine where tunnels are likely to be found, in terms of the physical environment. The study includes the topography, the drainage, the type of soil, and the hydrology. Representative models were made, including all of the known terrain characteristics, and we again decided where tunnels should be found. The comparison of the known locations with the predictions of where tunnels should be, gave a high correlation. The analysis indicated that the tunnels could be readily constructed and then the systems concealed in most of the areas that were identified as suitable on the maps of Vietnam. These suitable areas constitute about 50% of the total area that we looked at in Vietnam.

The depth of the tunnel is largely restricted only by the intersection of the tunnel with either the ground water table or with the hard laterite layer. In general this limits deep tunnels and multi-layer tunnels to the higher ground elevations, mostly those more than 10 meters above sea level. The map indicates certain areas as being about at sea level. These, in general, do not have tunnels. The ground isn't strong enough and the water level is relatively close to the surface.

ARPA then asked the Waterways Experiment Station (WES) to make a much more detailed study of existing tunnels. The Waterways Experiment Station report is entitled "Environmental Characteristics of Tunnels in South Vietnam." It includes the tunnel geometry, the surface composition and the microclimate, including the relative humidity in tunnels, around tunnel entrances and above tunnels but removed from the entrances. WES looked at the vegetation growing over known tunnels to determine whether it would be possible to detect the tunnels in terms of the effect on vegetation, due perhaps to the increased water available for the rest of the vegetation. WES also took some visual and infrared photographs from the air of these tunnel complexes. They found no single characteristics to identify them. It was not possible to locate the tunnel in terms of the vegetation growth pattern.

In addition to trying to find out what the problem really is, we have also tried to develop techniques for locating tunnels. We had a survey of the literature conducted for us by the Battelle Memorial Institute, which prepared a report entitled "Digest of Literature Relating to Detecting Buried Ferrous Objects and Earth Voids by Magnetic Methods." We also had Rand do a study for us on remote sensors for detecting tunnels. Rand considered gravity anomalies, magnetic anomalies; anomalies of the electrical conductivity of the earth, etc. Rand also considered the problems in making seismic measurements and electrical measurements in the field.

We then tried to use these data to develop devices for finding tunnels. We had the Applied Physics Laboratory (APL) of the Johns Hopkins University try to adapt the sonar technique, used by the Navy to find ships and submarines, to find tunnels in the ground. The sonar system APL used generated relatively high frequency seismic signals, which were attenuated very rapidly in the ground. There are three modes of seismic energy propagation in the ground, which interfered with each other, in this study to used sonar to detect tunnels. In addition, the propagation path is bent because the characteristics of the soil change with increasing depth; the soil is loose near the surface, and then becomes compacted because of the increasing pressure with increasing depth. Thus a seismic detector, separated from the source of the seismic signal, picks up several signals even in the absence of a tunnel, because of inhomogeneities in the ground. Thus, this high frequency seismic approach did not work. APL is now preparing its final technical report.

We also investigated the possibility of using a microwave radiometer, based on data provided by the Space General Corporation (SGC). These data showed that the SGC microwave radiometer detected caves and voids near a road in California. The microwave radiometer was used to measure "black body" radiation coming from the ground in a narrow band of microwave frequency. It was claimed that the radiometer measured the radiation coming from the earth, down to the depths of the caves which were found. The gas present in a void radiates much less than the earth would, if there were no void. Thus, by looking for a negative signal, it should be possible to detect an anomoly. However, the attenuation of the earth for frequencies in the microwave region, from 3 GHZ to 30 GHZ, the frequencies used by SGC, is very high.

I enlisted the cooperation of the Ballistic Research Laboratories (BRL), which used its own radiometers in this region to look at the training tunnel at the Aberdeen Proving Ground. That tunnel is a large tunnel with only one ft. of overburden and with a galvanized iron roof. This should make a very good target for a microwave radiometer if it were possible to detect tunnels using this technique. However, BRL could find no correlation between the radiometer signals and the tunnel location, as the area above and near the tunnel was scanned. This approach was then abandoned.

ARPA has also sponsored work on a radar approach to tunnel detection. This program was initiated at the MIT, Lincoln Laboratory during the summer of 1966. This radar, called GEODAR, uses an antenna which is very closely coupled to the ground. The antenna, which is roughly one meter square, is held sufficiently close to the surface of the ground so that much of the rf energy goes into the ground and relatively little is radiated upwards. A dc pulse, about 5 nanoseconds long, is applied to the relatively low Q antenna. The initial return signal is the reflection from the surface of the ground, which is not picked up because the receiver is not yet turned on. The rf energy is attenuated as it propagates down into the ground. It is scattered by any anomolies in the ground, such as tunnels, big rocks, or changes in the electrical characteristics of the earth caused by layers of different materials. Some of the scattered energy returns to the antenna, which now serves as the receiver antenna. The signal is displayed either on a chart or on an oscilloscope. The GEODAR has been tested in four locations in the United States with some success. The Lincoln Laboratory's report shows pictures indicating that they have actually found the tunnels in these areas.

Because of the possibility that the Marine position at Khe Sanh was being infiltrated with tunnels, ARPA arranged for the Lincoln Laboratory to contract with Sylvania to build some GEODAR units to go to Vietnam. The first two are now scheduled to be shipped out Friday, which is roughly three weeks after the contract was signed with Sylvania. In order to get this equipment produced in this short time, it had to be built out of commercially available equipment.

In order to have the close coupling required between the antenna and the ground, the antenna should be somewhere between 2 and 12 inches above the ground, with optimum results being achieved when the antenna is roughly 4 to 8 inches above the ground. The antenna is actually being installed in a sled which can be dragged over the ground.

The GEODAR can be operated in a 1/4 ton truck, a 3/4 ton truck, or an Army personnel carrier, to provide some protection for the people who are operating the equipment. The antenna is connected to the vehicle by a 75 ft. long cable, and the sled itself is pulled by a rope which allows the distance between the sled and the vehicle to be adjusted from about 15 ft to 60 ft.

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DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY MATERIEL COMMAND
WASHINGTON, D.C. 20315

IN REPLY REFER TO
AMCPM-SMO

30 April 1968

SUBJECT: Interagency Conference on Tunnels

Chief of Research and Development
ATTN: Dr. James I. Bryant
Physical and Engineering Sciences Division
Department of the Army
Washington, D. C. 20310

1. (U) The remarks made by COL Bezich at subject meeting are not submitted for reproduction because of the special classification of the work with which we are involved; however, there is some information which should be of interest and value to those interested in detection of the act of tunneling as opposed to the detection of the tunnels.

2. (~~C~~) The attached paper provides some information on a test of MAGID (Magnetic Intrusion Detector) which is effective in the detection of movement of magnetic objects which are within the range of its sensitivity. The supply of these items is controlled by Defense Communications Planning Group; however, it appears that some MAGID's may be made available for other than special project use.

3. (U) Mr. Martin J. Damgaard, AMCRD-J, has been designated as "Detection Coordinator" for AMC. Further participation in this area by this office is not anticipated at this time.

1 Incl
as

[illegible]
Colonel, CE
Project Manager
Special Mission Operations

cy furnished:
AMCRD-J (Mr. Damgaard)
AMCRD-O (COL Buerger)

GROUP 3
~~DOWNGRADED AT 12 YEAR INTERVALS~~
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~~SPECIAL HANDLING REQUIRED, NOT~~
~~RELEASABLE TO FOREIGN NATIONALS~~

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MAGID (Magnetic Intrusion Detector)

1. (U) The Magnetic Intrusion Detector (MAGID) (shown in attached picture) is a omnidirectional device specifically designed to operate as an external sensor for single or combination mode use with the Hand Emplaced Seismic Intrusion Detector (HANDSID). The MAGID is buried adjacent to the path or trail upon which traffic is expected. The device senses the changing magnetic field produced by the movement of a metallic object through the earth's field, in the vicinity of the detector. The equipment was designed for maximum ease of installation by field personnel with maintenance-free, unattended operation for a period of 50 days.

2. (U) The MAGID output has been modified so that it may be connected to an annunciator (shown in attached picture) rather than the HANDSID. Connected to the MAGID by a single pair of wires, the annunciator provides an audible and numerical read-out of each activation of the MAGID.

3. (C) The Annunciator is contained in a 6" x 7" x 2½" package weighing 5 3/4 lbs. and is powered for 120 days by a 6.75 volt battery. When a magnetic disturbance takes place within the field of sensitivity, roughly football shaped (65 ft. long by 50 ft. wide), the Annunciator sounds a tone, lights an indicator lamp, and records the indication on a cumulative counter.

4. (C) The MAGID (wt. 18 lb.) is installed by burying the device (solenoids) up to 10 feet from the point of furthest approach in the desired area of protection. As an intruder passes through the MAGID's field of sensitivity, a voltage is induced into the device. This voltage is amplified and sent to a logic circuit which in turn recognizes the voltage as an intruder signal. The logic circuit then sends a signal which produces the interface alarm signal at the output connector. A single multi-voltage battery is used to power the MAGID, and battery life under typical operating conditions is approximately 50 days.

5. (C) In a test performed at Edgewood, a one pound coffee can, a bayonet and the use of an entrenching tool were consistently detected 11 ft. below ground by the MAGID. Metal fence posts and live telephone wire located close to the MAGID did not produce any false alarms. Concertina wire located at 28 ft. did not cause any alarms even though it was shaken by hand as much as 1 ft. in either direction. However, using an AN/PRC-25 radio 25 ft. from the device did produce false alarms, although a Power Generator (30 KW) located at 50 ft. did not produce activations.

6. (C) The use of the MAGID will not detect tunnels per se, but will detect the movement of ferrous material in tunnels with a high degree of confidence.

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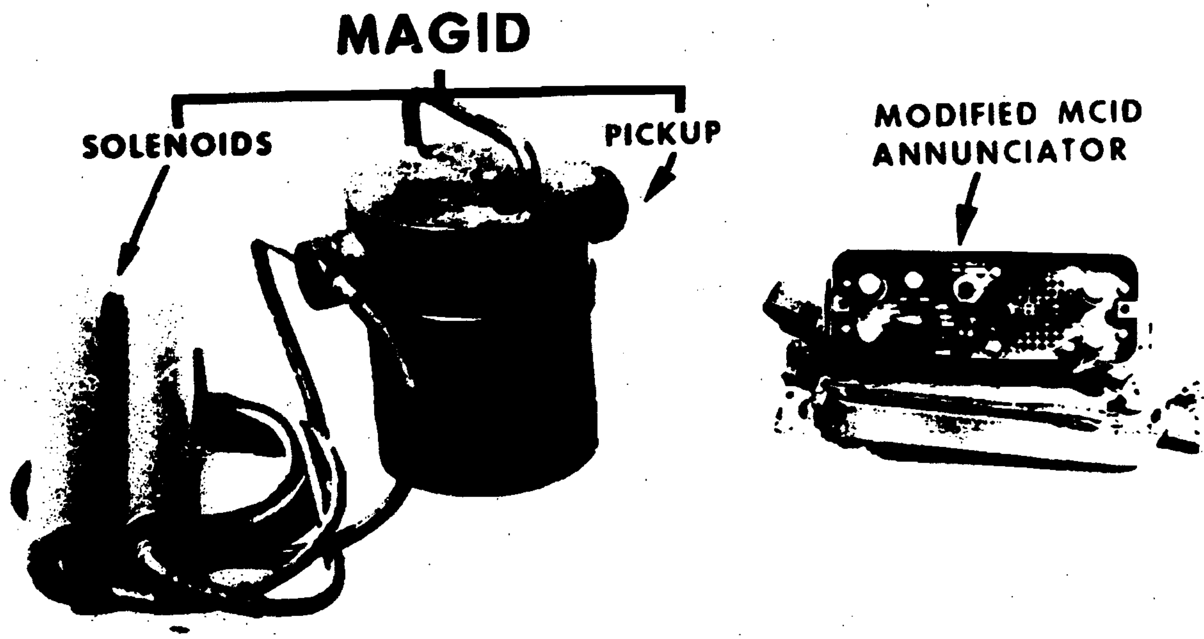

MAGNETIC TUNNELLING DETECTOR (MTD)

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CRDPES 3 April 1968

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COMPENDIUM
INTERAGENCY CONFERENCE ON THE TUNNEL PROBLEM (U)

29 October 1968

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OFFICE OF THE CHIEF
OF
RESEARCH AND DEVELOPMENT
DEPARTMENT OF THE ARMY

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INTERAGENCY CONFERENCE ON THE TUNNEL PROBLEM (U)

29 October 1968

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Dr. Ivan R. Hershner, Jr.

Chairman

Dr. James I. Bryant

Deputy Chairman

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CONTENTS

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PREFACE

The contents of this compendium are the reports of the Second Interservice Meeting on Tunnel Warfare held at the OCRD Highland Building, 29 October 1968. In general, the contents are representative status reports on the research and development and administrative aspects of ongoing programs. Two of the objectives of the 29 October 1968 conference were to update the assessment of the status of the tunnel problem in Vietnam and the requirements for capabilities to counter the tunnel threat. In satisfying these objectives, the conference was only partially successful. Notably lacking were presentations in this area of concern by ACSFOR, ACSI and ACTIV. With the exception of the Draft Proposed Qualitative Materiel Development Objective presented by CDC and the presentation by the Office of the Scientific Advisor, USARV, the research and development personnel at the conference received little insight into future requirements related to tunnel warfare.

The conference was considered to be highly useful in updating the status of technical programs. This compendium therefore, makes available a permanent record of this aspect of the conference proceedings. It is intended that the contents will provide for the participants a convenient reference and guide in the planning and guiding of future tunnel research and development efforts.

Expressions of thanks are extended to all the participants for their oral and written presentations and their participation in discussions, all of which have helped make possible the successful execution of the conference and the compendium.

Ivan R. Hershner Jr.

IVAN R. HERSHNER, JR.
Chairman

AGENDA

Conference of Interservice Coordinating Group
for Tunnel Program
29 October 1968
0900 hours

Introductory Remarks - Dr. Ivan R. Hershner, Jr., Chief, Physical and Engineering Sciences Division, OCRD, - Conference Chairman

Status of Tunnel Problem in Vietnam - Mr. William Marroletti, Office of the Science Advisor, Military Assistance Command Vietnam

Tunnel Programs and Responsibilities - Mr. David M. Lipnick, HQ, US Army Materiel Command, Washington, D.C.

Current Status and Future Plans of USMERDC's Tunnel Detection Program - Mr. Manfred Gale, Mr. Karl Steinbach, Mr. James Whalen, US Army Mobility Equipment R&D Center, Fort Belvoir, Virginia

Tunnel Detection, Tunnel Explorer Locator, Locator and Communicator, Canine Detection of Tunnels - Mr. Milton Cutler, Mr. Jacob Wenig, Limited War Laboratory, Aberdeen Proving Ground, Maryland

Tunnel Environmental Studies. Tunnel Explorer, Locator and Communicator, Radio Frequency Tunnel Detector - Mr. Billy R. Davis, Waterways Experiment Station, Vicksburg, Mississippi

Tunnel Detection Experiments at ORNL - Mr. Jay C. Pigg, Oak Ridge National Laboratory, Oak Ridge, Tennessee

ARPA's Program Related to Tunnel Problems - Mr. Charles Ravitsky, Advanced Research Projects Agency, OSD/ARPA/AGILE

Tunnel Detection Research at ECOM - Dr. Douglas C. Pearce, US Army Electronics Command, Fort Monmouth, N.J.

Status Report on Capabilities for Tunnel Denial - Mr. Joseph Sansonetti, Edgewood Arsenal, Maryland

Tunnel Destruction. Requirements, Existing Equipment and Results of Field Evaluation - Mr. Martin Bachthaler, US Army Munitions Command, Dover, N.J.

Liquid Tunnel Destruction System. Safety in Handling and Storage of Liquid Explosives - Mr. Bela Torok, Mr. Shepherd Levmore, Picatinny Arsenal, Dover, N.J.

Tunnel Requirements and Programs - Mr. J. C. M. Jones, Office of the Scientific Advisor to the Military Board, Australian Military Forces, Canberra, Australia

Considerations on Tunnel Doctrine - MAJ Arthur Torf, US Army Combat Developments Command, Fort Holabird, Maryland

The Anthropomagnetometer - Dr. Z. V. Harvalik, US Army Advanced Materiel Concepts Agency, Scientific Consultant Staff, Washington, D.C.

Group Discussion: Objective Research and Development Programs to Counter Tunnel Warfare - LTC Louis G. Klinker, OCRD, Discussion Leader

INTRODUCTORY REMARKS

Dr. Ivan R. Hershner, Jr.
Chief, Physical and Engineering Sciences Division
Office of the Chief of Research and Development
Department of the Army
Washington, D.C. 20310

Good morning, gentlemen.

This conference is the second interagency meeting convened to provide a means for overall coordination of research and development programs related to countering tunnel warfare, and to assess the extent of responsiveness of these programs to Department of Defense needs.

As has been the case in past meetings, the emphasis today will be on informality. Each of you represents an agency that has agreed to coordinate and discuss our respective roles related to the tunnel problem. The overriding objective is to determine how we might better work together to generate capabilities for countering the present and future threats of tunnel warfare. With the wide technical and managerial representation here today, a mechanism is provided for discussing and evaluating the broad overall aspects of this problem area.

In order for endeavors of this type to be successful, it is, of course, important that they take place in an atmosphere of active participation, of objective thought and with the general attitude of give and take. We thus proceed with the hope that solutions arrived at through the deliberation of the participants here are superior to those generated by isolated factions.

With these brief comments, I would like to open today's conference.

29 October 1968

US Army Materiel Command - Tunnel Programs and Responsibilities

Mr. David M. Lipnick

The US Army Materiel Command role in the Tunnel Program has been in the following areas:

PROGRAM	RESPONSIBLE AMC STAFF ELEMENT
1. Detection	Individual and General Equipment Office, Directorate of Development and Engineering
2. Destruction	Chemical-Biological-Nuclear Office Directorate of Development and Engineering
3. Denial	Chemical-Biological Nuclear Office Directorate of Development and Engineering
4. Exploration	Munitions Division Directorate of Materiel Requirements

These areas of the AMC Tunnel Program will be covered in this conference as follows:

1. Detection -	By representatives of US Army Mobility Equipment R&D Center of Fort Belvoir and US Army Electronics Command
2. Destruction -	By Mr. Martin Bachthaler of US Army Munitions Command and representatives of Picatinny Arsenal, insofar as current work. I will give a very brief summary of some past work.
3. Denial -	By Mr. Joseph Sansonetti of Edgewood Arsenal
4. Exploration -	I will briefly cover this area, which is now history, insofar as AMC is concerned.

Tunnel Destruction

Initial requirement for this work was received in February 1965 under ENSURE No. 111 for a method for the destruction of Viet Cong Tunnels. From this requirement envolved the acetylene system which is designated the XM69 Tunnel Destruct Demolition Set.

The XM69 Demolition Set consists of acetylene generators, oxygen converters, blowers, and an accessory set.

450 XM69 sets were shipped to Vietnam starting in November 1966, and in January 1968 USARV forwarded their evaluation which concluded the XM69 is less effective than other demolitions normally used to destroy tunnels, and recommended that R&D efforts be expedited to provide a more suitable system. In response to this recommendation, the work started on a liquid explosive system that you will hear about from the Munitions Command and Picatinny Arsenal representatives.

Tunnel Exploration Kit

Previous to AMC becoming involved in tunnel exploration, in August 1966 the Limited War Laboratories had shipped some tunnel exploration kits to VN for evaluation. This resulted in a requirement being submitted under ENSURE No. 64 for a kit to be used in exploration of tunnels for denial and intelligence. This kit did not involve any development, only purchase of required components, such as pistol, magazines, silencers, lanterns, batteries, and ear plugs. The kits were assembled by Natick Laboratories, and 250 were shipped to Vietnam in May 1968.

USAMERDC TUNNEL DETECTION EFFORTS

Current Status and Future Plans

as Presented by MERDC Representatives (U)

Conference of Interservice Coordinating

Group for Tunnel Program

29 October 1968

at

DCRD Highland Building

GROUP 3
DOWNGRADED AT 12 YEAR INTERVALS
NOT AUTOMATICALLY DECLASSIFIED

Summary:

(~~C~~) Since the last meeting in April 1968, two (2) portable seismic detectors have been successfully tested by ACTIV in Vietnam. Modifications resulting in reduced size and weight, improved handling and more rapid search operations have been accomplished, and advanced models are ready for shipment. SEA evaluation of a light weight, portable UHF detector is scheduled for Nov/Dec of this year. In coordination with other AMC Laboratories, a Research Program directed towards the development of improved detection systems suitable for more rapid scanning of extended areas is being staffed. This research program will be carried out concurrently with the advanced engineering development of the portable tunnel detectors.

Discussion:

1. Portable Detector Development

(~~C~~) Two types of man portable tunnel detection equipment are currently in the test and evaluation phases of development. These types are seismic and electromagnetic.

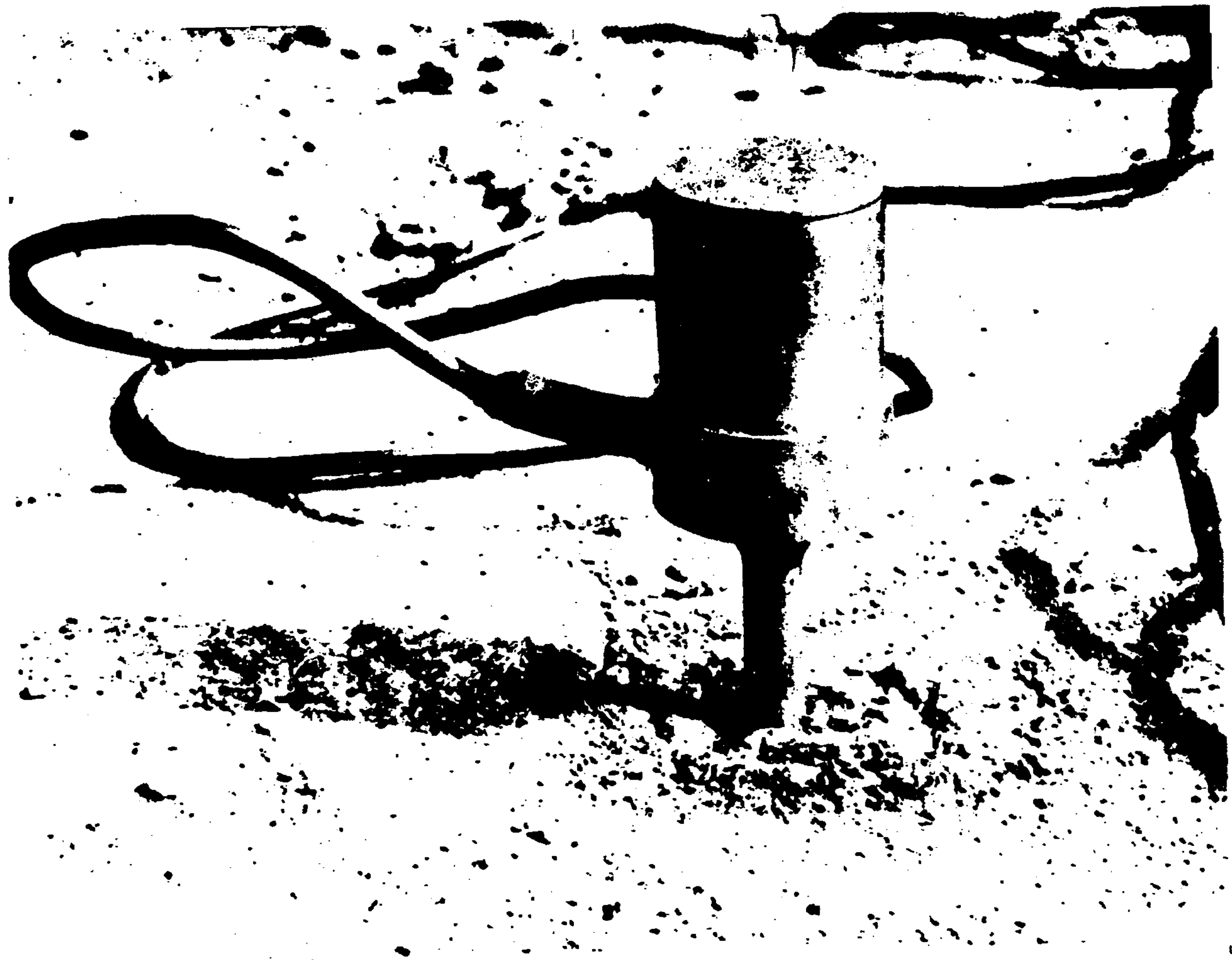
(~~C~~) Hardware procurement of the seismic detectors began in August of 1967, when a contract was awarded for the design, fabrication and testing of ten ruggedized experimental prototype models suitable for testing in Vietnam. The performance design goals for these units were for: Tunnel detection depths of at least 10 feet and search rates of at least 360 feet per hour; a battery life of at least 2 hours on internal batteries and at least 8 hours on external batteries; and, physically, the system must be light and small so that it could be transported by not more than two men.

(~~C~~) Photograph one depicts the resultant seismic system as it appeared while undergoing tests in Vietnam in April of this year. The system consists of an electronic package, a transmitting transducer, and a receiving transducer which is buried in the grass and not visible here. The electronic package contains the CRT A-scope display, all control and timing circuits, a high voltage dc-dc converter for powering the transmitting transducer, and internal batteries for powering the system. Storage for the receiving transducer and auxillary equipment is provided in the rear of the case. A detachable leg is provided so that the operator can relieve himself of the weight during soundings.

(~~C~~) The transmitting transducer consists of a two foot long stack of piezoceramic elements, resistive-inductive components to control the seismic waveform (located in the top of the transducer), and a coupler for coupling the acoustic energy from the piezoceramic stack into the soil. Two types of couplers are provided with this system. One is an aluminum cone which attaches to the base of the transducer. The other is a circular plate which is interchangeable with the cone. The transmitting transducer requires 2000 volts dc for operation. This voltage is supplied from the electronics package through a detachable cable.

(~~C~~) The receiving transducer, shown in photograph two consists of a piezoceramic accelerometer element and a preamplifier. The receiver is coupled to the ground by a spike. Supply voltage for the preamp and signal from the transducer is transmitted by a cable which is connector coupled to the electronics package.

Photograph 1 - Ruggedized Experimental Seismic Tunnel Detector



Photograph 2 - Seismic Tunnel Detector Receiving Transducer

(C) In operation, the transmitter and receiver are coupled to the ground and a seismic impulse approximately 1 millisecond in duration is generated by the transmitting transducer. The receiving transducer detects the directly transmitted seismic wave as well as echoes. These waveforms are displayed on a CRT as a time versus amplitude plot. Consequently, the arrival time as well as amplitude of the complex waveform can be observed. This type of display allows the system to be operated in a reflective mode or a refractive like mode.

(U) Two of the ruggedized experimental detectors were tested in Vietnam by ACTIV during April and May of this year. Photograph three shows the unit being operated around one of the buildings at Long Binh. Note the auxillary battery being used in this case. Photograph four shows the unit being tested in a second environment. Photograph five shows the unit being tested in still a third environment.

(U) As a result of this test and evaluation, ACTIV released a report in which the findings, conclusions and recommendations were summarized. I will now share this summary with you.

Findings

(C) a. Teams using the Seismic Tunnel Detector were able to detect and accurately map known tunnels.

(C) b. One half of the trainees with less than a high school education and GT and EL area scores of less than 90 were rated as marginal operators.

(C) c. Four out of five of the trainees with a high school education and GT and EL scores of greater than 90 were rated as above average operators.

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Photograph 3 - Experimental Seismic Tunnel Detector During ACTIV Tests

Photograph 4 - Experimental Seismic Tunnel Detector During ACTIV Tests

Photograph 5 - Experimental Seismic Tunnel Detector During ACTIV Tests

~~(C)~~ d. Seven operators out of thirteen were able to effectively employ the Seismic Tunnel Detector after three days training.

~~(C)~~ e. An experienced project engineer conducted the training program.

~~(C)~~ f. The evaluating unit stated that the storage oscilloscope greatly aided the training program and recommended its use for all future training.

~~(C)~~ g. Users considered the average minimum time per sounding in hard dry soil (2-3 minutes) excessive for any practical search.

~~(C)~~ h. Average minimum time per sounding in softer soil was 25 seconds.

~~(C)~~ i. Average minimum time to read and interpret the oscilloscope was 15 seconds per sounding.

~~(C)~~ j. The fastest search pattern used by the evaluating unit was moving the transmitting and receiving transducers in a leap-frog fashion.

~~(C)~~ k. The transmitting transducer failed at the cap screw holes and at the power cable connection, (due to the procedures used to couple the transducer to hard dry soil,) (Photograph six shows this failure.)

~~(C)~~ l. The soft aluminum point on the receiving transducer bent when used in hard dry soil.

~~(C)~~ m. Users desired a method of providing a hard copy print of the readings for efficient operations.

~~(C)~~ n. A three man team was preferred by the evaluating unit to operate the Seismic Tunnel Detector most efficiently.

~~(C)~~ o. No spare parts were available for maintenance support.

~~(C)~~ p. Users considered the auxillary battery unnecessary and a burden.

Photograph 6 - Transmitting-Transducer Failure During ACTIV Tests

Conclusions

(U) a. In its present configuration, the Seismic Tunnel Detector is unsuitable for use in Vietnam.

(U) b. Personnel chosen to operate a detector with the present readout system should be high school graduates and have GT and EL area scores of 90 or better.

(C) c. A maintenance support package is needed to support sustained operations.

(C) d. Training of personnel should be conducted by experienced personnel equipped with proper training aids.

Recommendations

(U) a. Delete the auxillary battery pack and battery charger from the Seismic Tunnel Detector set.

(C) b. Continue developmental work on the Seismic Tunnel Detector.

(U) (1) As a matter of first priority, modify the transmitting transducer to provide a more rapid means of coupling to hard dry soils.

(U) (2) Strengthen both the transmitting and receiving transducers.

(C) (3) Concurrently, develop a device to provide a printed copy of each reading with a means of keying it to a search map. Within the state of the art, automate the interpretation process. The device must not add to the weight or size of the detector.

(U) c. When recommendations b(1) and b(2) have been accomplished and CONUS testing completed, return the detectors to Vietnam to continue the evaluation.

(~~C~~) d. Develop a maintenance support package to be deployed with future tunnel detector equipment.

(~~C~~) e. Provide a "NET" team to train operators and maintenance personnel on future tunnel detection equipment.

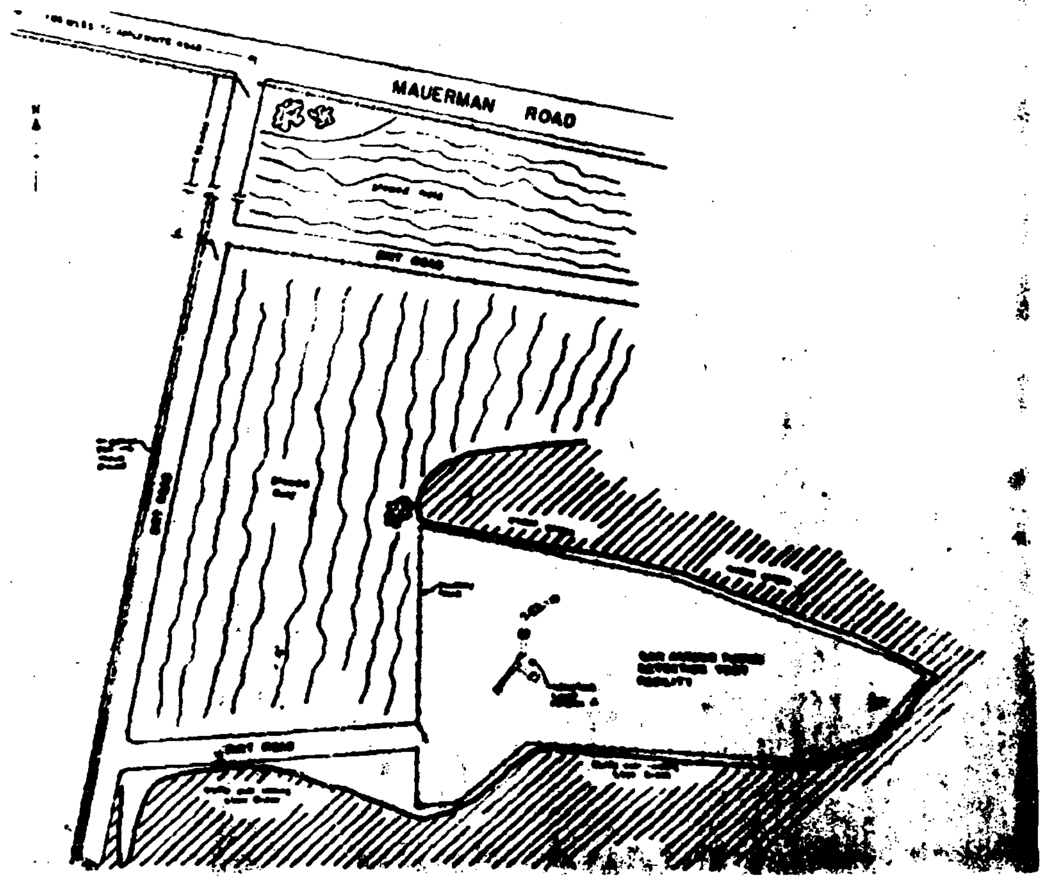
(~~C~~) f. Personnel selected to be trained as operators on a seismic tunnel detector using the current readout should be limited to high school graduates with GT and EL aptitude scores of 90 or better.

(~~C~~) In accordance with the ACTIV recommendations, modifications of the seismic detectors were initiated in June of this year. From the on-site reports it was apparent that the major operational difficulties resulted from the hardness of the soil in which the unit had to operate. As shown by photograph seven, the earth was very dry, hard and flaky. The soil was not easy to penetrate even with a spike such as shown in photograph eight, and to get a cone as large as the base of the transmitting transducer to penetrate without prior preparation of the soil was virtually impossible.

(U) One of the first steps in carrying out the ACTIV recommendations was to establish a test facility where various ground conditions could be produced. A tunnel test facility had been constructed near San Antonio, Texas for testing the ruggedized detectors just described, and in July of this year this facility was equipped with protective structures so that the soil moisture content in the tunnel area could be controlled to simulate soil conditions in Vietnam. The tunnel facility is located on a plateau as shown in photograph nine. An effort was made to select a site where the

Photograph 7 - Vietnam Soil Characteristics During Dry Season

Photograph 8 - Demonstration of Hardness of Vietnam Soil



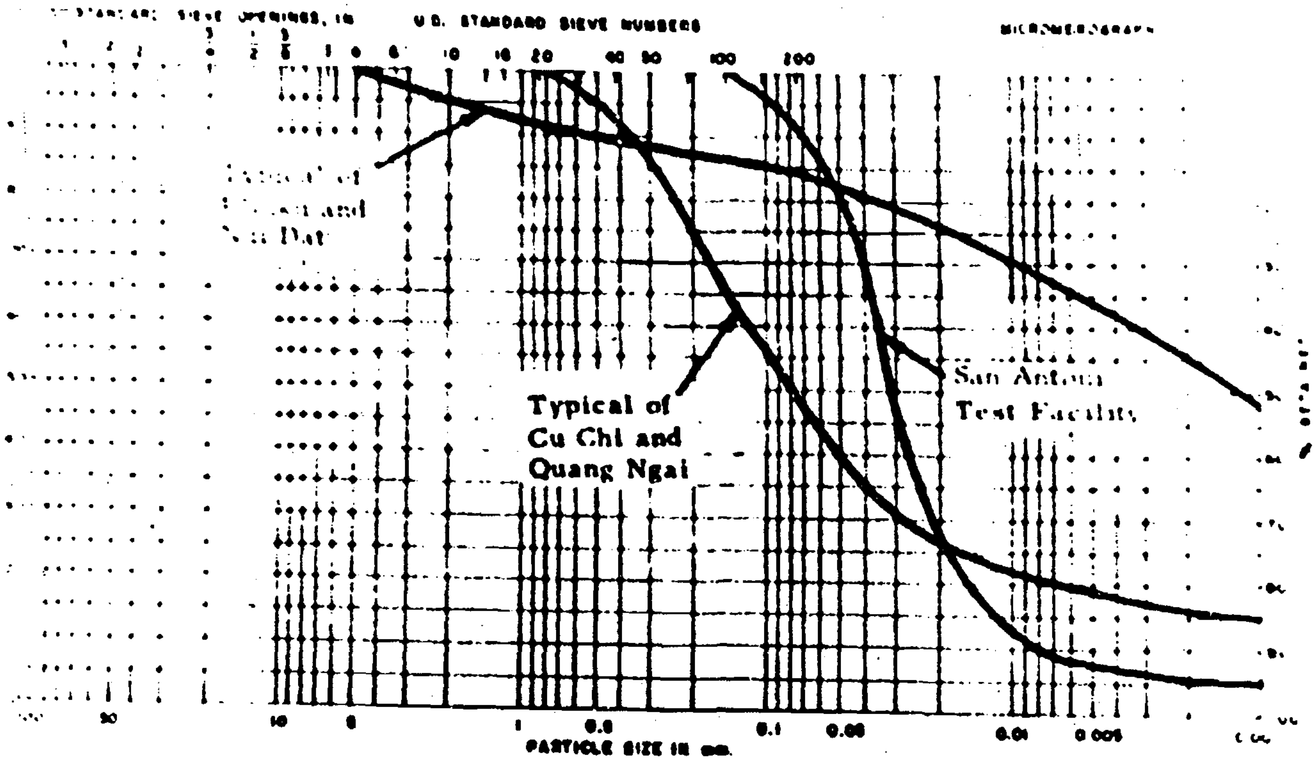
Photograph 9 . SAN ANTONIO TUNNEL DETECTION TEST FACILITY FIELD SITE BOUNDARIES AND TUNNEL COMPLEX soil particle distribution closely approximates known Vietnam soils. Photograph ten shows the particle distribution at the San Antonio site as well as sites at Pleiku, Nui Dat, Cu Chi, and Qnang Ngai. As can be seen, the San Antonio site is a reasonable compromise between the various sites. As shown in Photograph 11, the San Antonio tunnel complex consists of passage ways as well as rooms. The overburden depth ranges from 2.7 feet at the shallow room to 15.8 feet at the deepest section. Undersized shoring is used inside the tunnel so that experiments can be conducted inside the tunnel without fear of collapse. Photograph 12 shows the inside of the shallow room. Photograph thirteen is a view of one of the depth transitions. The tunnel complex was dug by tunneling from underneath to simulate the Vietnamese tunnels. The sections of the tunnel complex covered by a canopy dried to a point where they simulate very well the hard soil encountered in Vietnam at the end of the dry season. Other uncontrolled areas more nearly simulated the Vietnam soil during more rainy seasons.

(C) In keeping with the recommendations of the ACTIV report, modifications to the seismic tunnel detectors were begun in June of this year. These modifications consisted basically in:

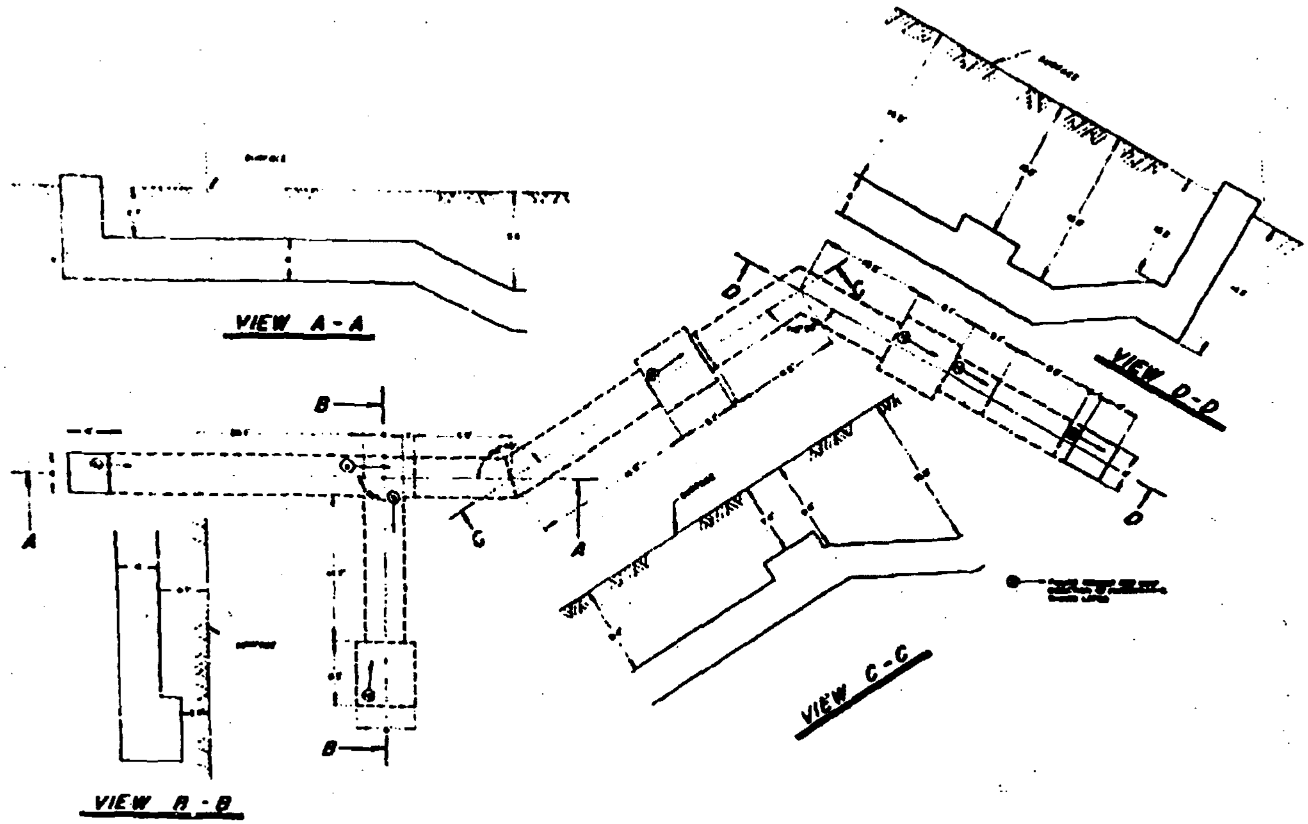
(1) Development of a surface seismic coupler which could quickly be coupled to the soil surface.

(2) Hardening of the transmitting transducer to overcome the experienced cap failure.

(3) Reducing the size and weight of the system for greater ease and flexibility of operation.



Photograph 10 **SOIL PARTICLE DISTRIBUTIONS FOR SAN ANTONIO TUNNEL DETECTION TEST FACILITY AND FOUR SITES IN SOUTH VIETNAM**



Photograph 11 CONSTRUCTION LAYOUT OF THE SAN ANTONIO TEST FACILITY TUNNEL COMPLEX

Photograph 12 - Shallow Room Inside San Antonio Tunnel Complex

Photograph 13 - Depth Transition Inside San Antonio Tunnel Complex

(U) Functionally the modified detectors are the same as the ruggedized units previously tested. Early this month the modifications to four seismic tunnel detectors were completed, and over the past three weeks a New Equipment Training Team has been training on these units. CPT Hatfield who heads this team will be telling us more about this activity a little later. The improvements in system size, weight and performance can best be illustrated by the comparison chart shown in photograph fourteen. One of the most notable improvements is search speed, which has improved almost an order of magnitude for hard soils.

(C) Photograph fifteen shows the modified equipment connected for normal use. Note that the cable between the transmitter and electronics is reconfigured to avoid the problems previously encountered. Quick disconnect connectors are installed on both ends so that the cable can be easily replaced if necessary. The present cable is much smaller and more flexible than the original because only low voltage is transmitted to the transducer. The high voltage dc-dc supply is now included in the transmitter. The receiving transducer connects into the transmitter, thereby reducing the multiplicity of cables to the electronic package. Note also the body weight assisted type coupler used with this transducer. When operating on hard soils the user places the transducer on the ground and stands on the rim of the coupler. The rim is then pressed down to the ground and an internal spring produces a load of approximately 100 pounds at the base of the transducer. When this type coupler is used the system is not operated in the pulse echo mode, because the extensive surface waves generated by this type of surface coupler tend

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PHOTOGRAPH 14

COMPARISON OF ORIGINAL AND MODIFIED SEISMIC TUNNEL DETECTORS

PHYSICAL	ORIGINAL	MODIFIED
Electronic Wt.	40 lbs.	22.4 lbs.
Electronic VOL.	1285 $in.^3$	880 $in.^3$
Transmitter Wt.	25 lbs.	20.8 lbs.
Transmitter Vol.	209 $in.^3$	192 $in.^3$
Total System Wt.	65 lbs.	43.2 lbs.
Total System Vol.	1494 $in.^3$	1072 $in.^3$
Percent Wt. Reduction		33.6 %
Percent Size Reduction		28.3 %
PERFORMANCE		
Nominal Search Speed (Hard Soil)	60 ft./hr.	500 ft./hr.
Internal Battery Life	8 hours	4 hours

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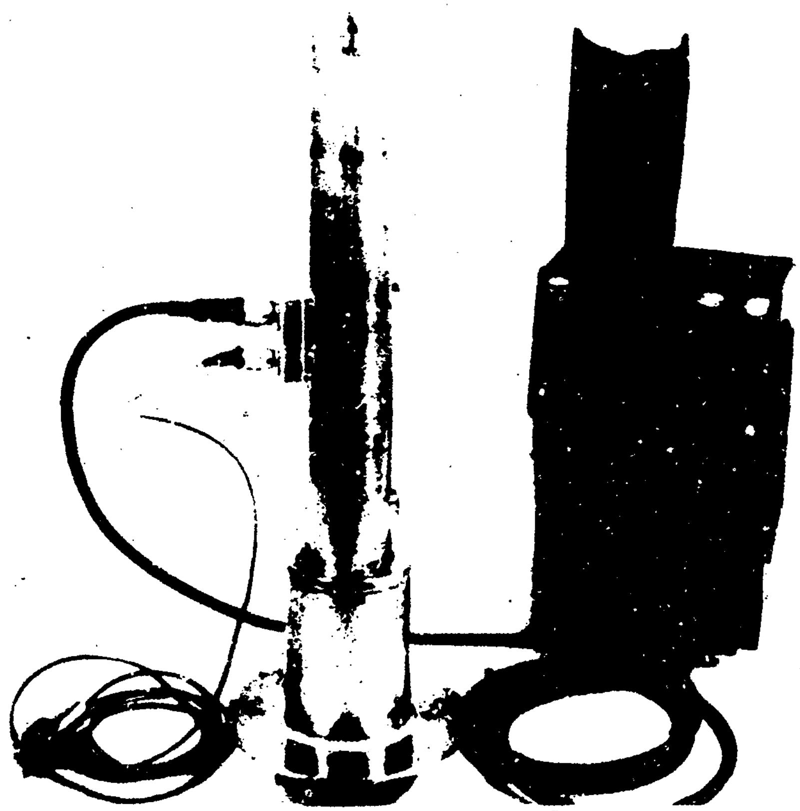
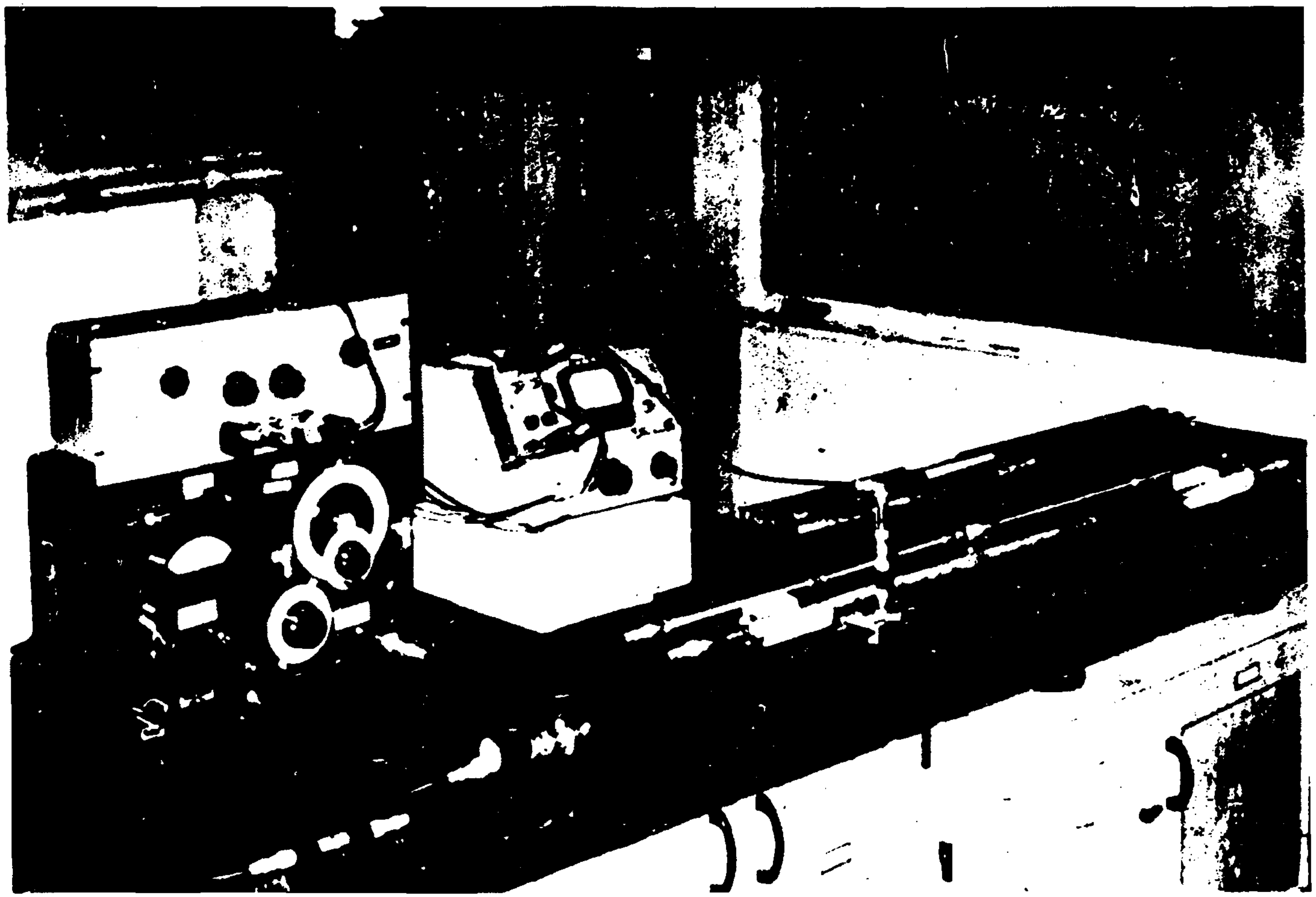


Photograph 15 - Modified Seismic Tunnel Detectors to mask echoes. However, horizontal propagation velocity increases considerably above a tunnel, and this is sufficient for detection purposes. This increase is caused by changes in the shear and compressional elastic parameters as a result of stress in the overburden of a tunnel. This phenomenon is less pronounced in cases of supported tunnels, but indications are that few tunnels are supported during construction. If supported tunnels become common place, the conical coupler can still be used with this transducer and the system can be used in a reflective mode in reasonably soft soils.

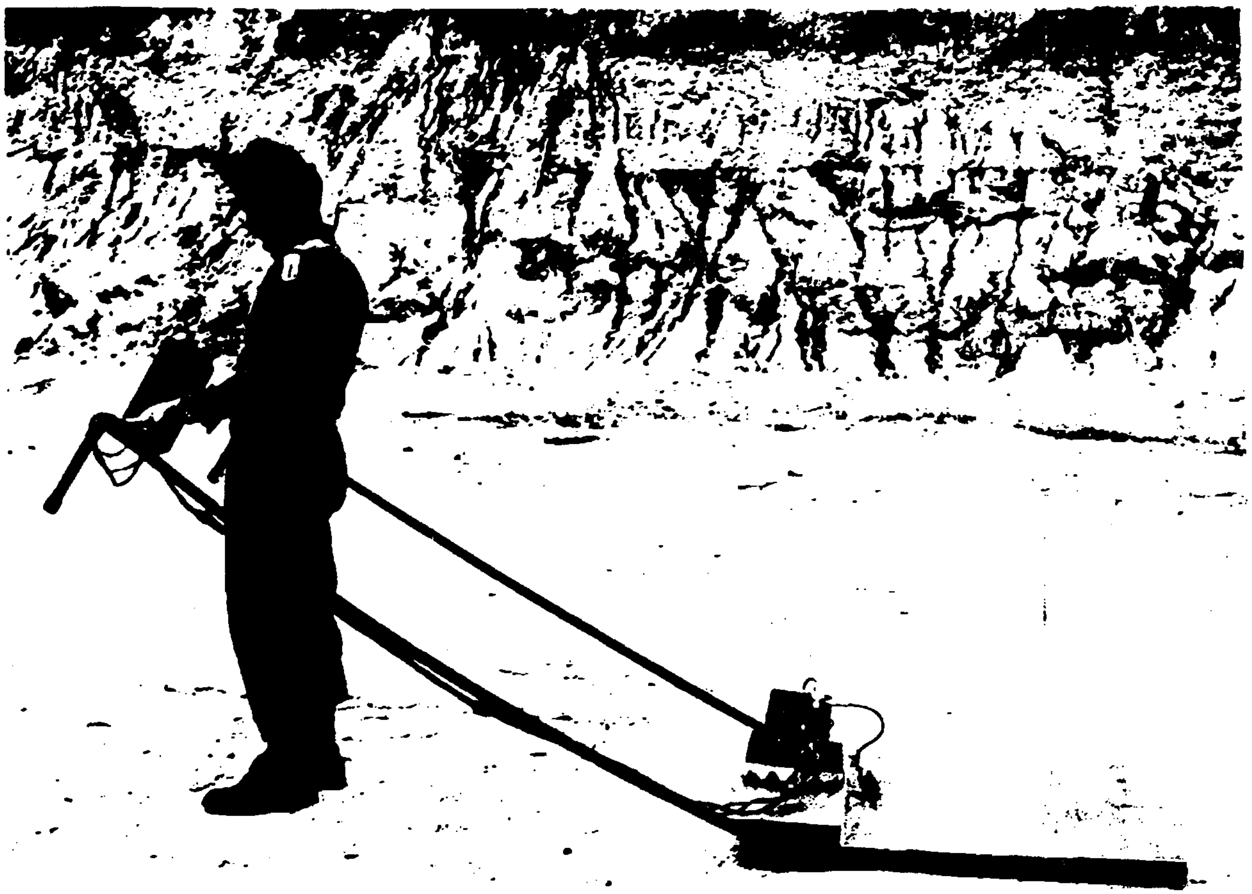
(U) Next, let us look at the second type of tunnel detector being developed at MERDC. This is a short pulse electromagnetic system which looks into the soil. In late 1966 and early 1967 in-house research was conducted to determine the feasibility of a soil penetrating radar system with sufficient bandwidth to detect a three foot diameter tunnel. One part of the in-house study was the measurement of soil attenuation as a function of frequency. Photograph <u>sixteen</u> shows the laboratory set up for measuring attenuation of soil samples contained in a coaxial line. This is a laborious but very accurate method of measuring soil attenuation. Measurements were made of soils from various parts of the U. S. and SEA. Attenuations were found to range between 2db/meter to greater than 50db/meter, but most soils were in the range of 12db/meter or less. These measurements indicated that a soil penetrating radar system would be feasible under many of the conditions examined.

~~(C)~~ In the fall of 1967 a contract was let for a man portable soil penetrating radar system. This system shown in photograph <u>seventeen</u> was

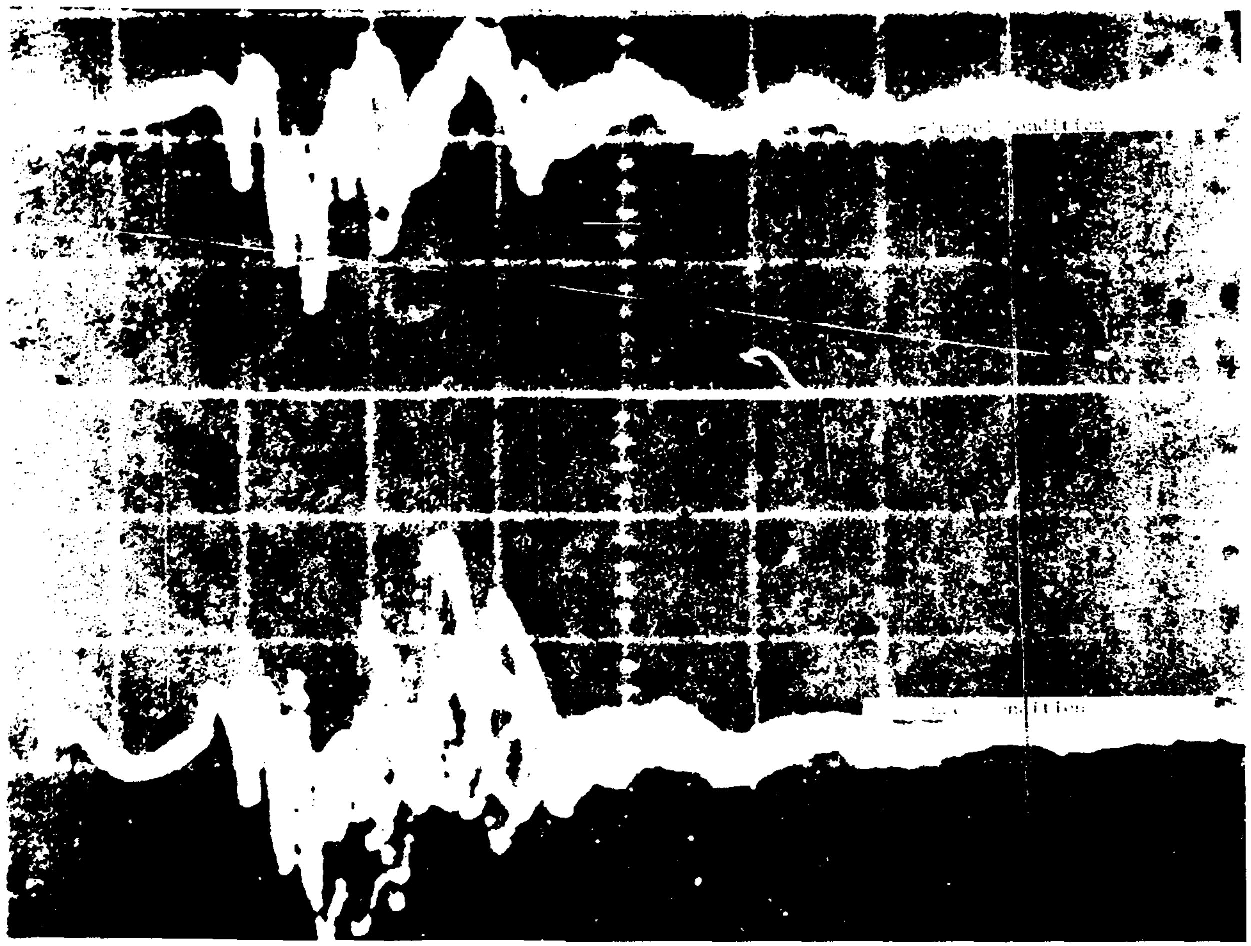


Photograph 16 - Test Set-up for Measuring rf Attenuation of Soil delivered in July of this year, and is currently undergoing test and modification. The present system consists of a battery and transmitter package, an A-scope display and control electronics package, and an antenna. The antenna shown here is a loop type similar to the Geodar antenna. This is essentially an immersed antenna which operates very near the ground and experiences the soil dielectric. Other antennas currently under test will be further developed for future systems. Experiments are being conducted on smaller, dielectric loaded units which can operate at a height of a few inches above the soil surface.

(~~C~~) A modified EM system will be available for evaluation in Vietnam later this year. This system will utilize the same basic antenna, but the electronics will be reconfigured for greater portability and maneuverability. An advanced model is concurrently under development and will be available early in 1969. The advanced model will utilize a smaller antenna and signal processing circuitry to simplify display interpretation. The present system uses an A-scope presentation. The multiple exposure of photograph eighteen shows the A-scope display while passing over a culvert as compared to passing through a non target area. A hard copy printout is being developed for use with the advanced EM system and will be available in March of 1969. The advanced detector is anticipated to have a detection capability of up to 15 feet in most soils. However, in highly attenuative soils the system will be inoperative. One of the problems in the EM system is to determine if the soil is to lossy to detect a target. This problem is being investigated by Dr. Pearce and Mr. Walker of ECOM, and we will hear more of this work later in the program.



Photograph 17 - Man Portable Electromagnetic Tunnel Detector

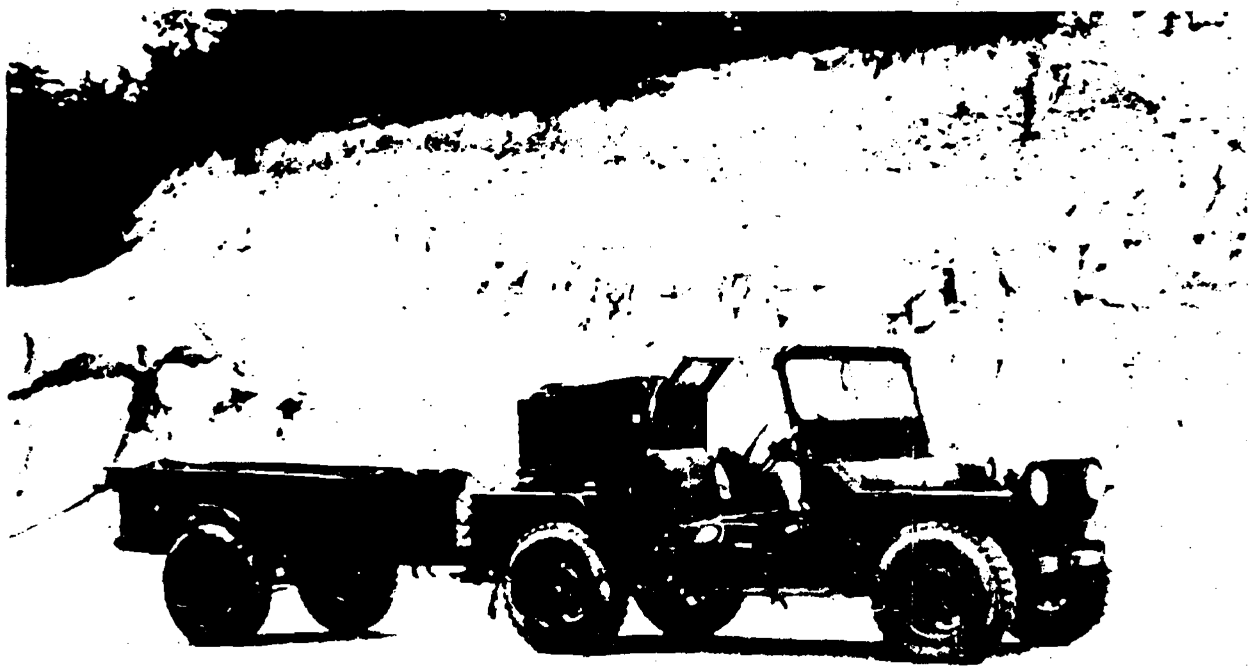


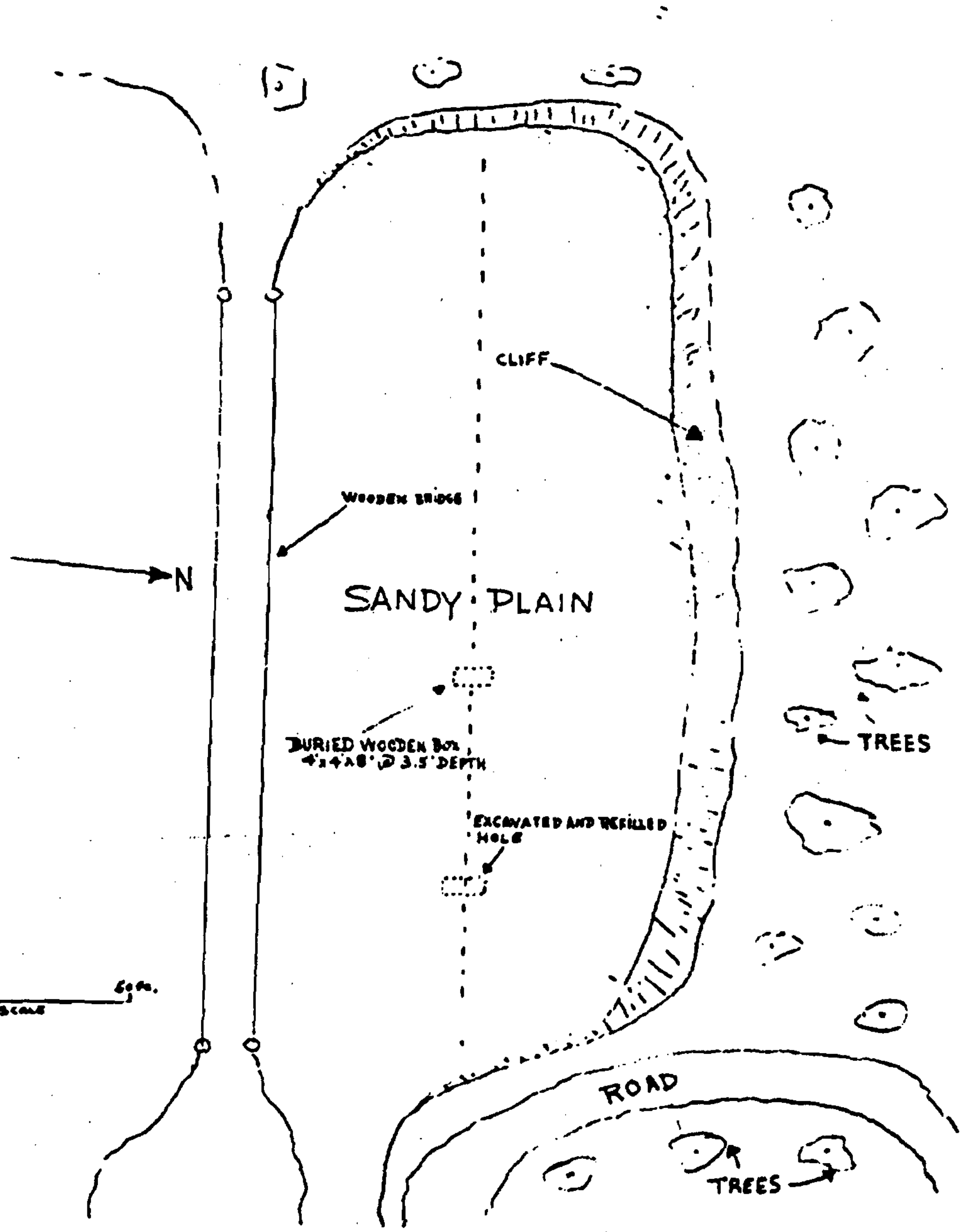
Photograph 18 - A-Scope Display of Electromagnetic Tunnel Detector

2. Evaluation of GEODAR

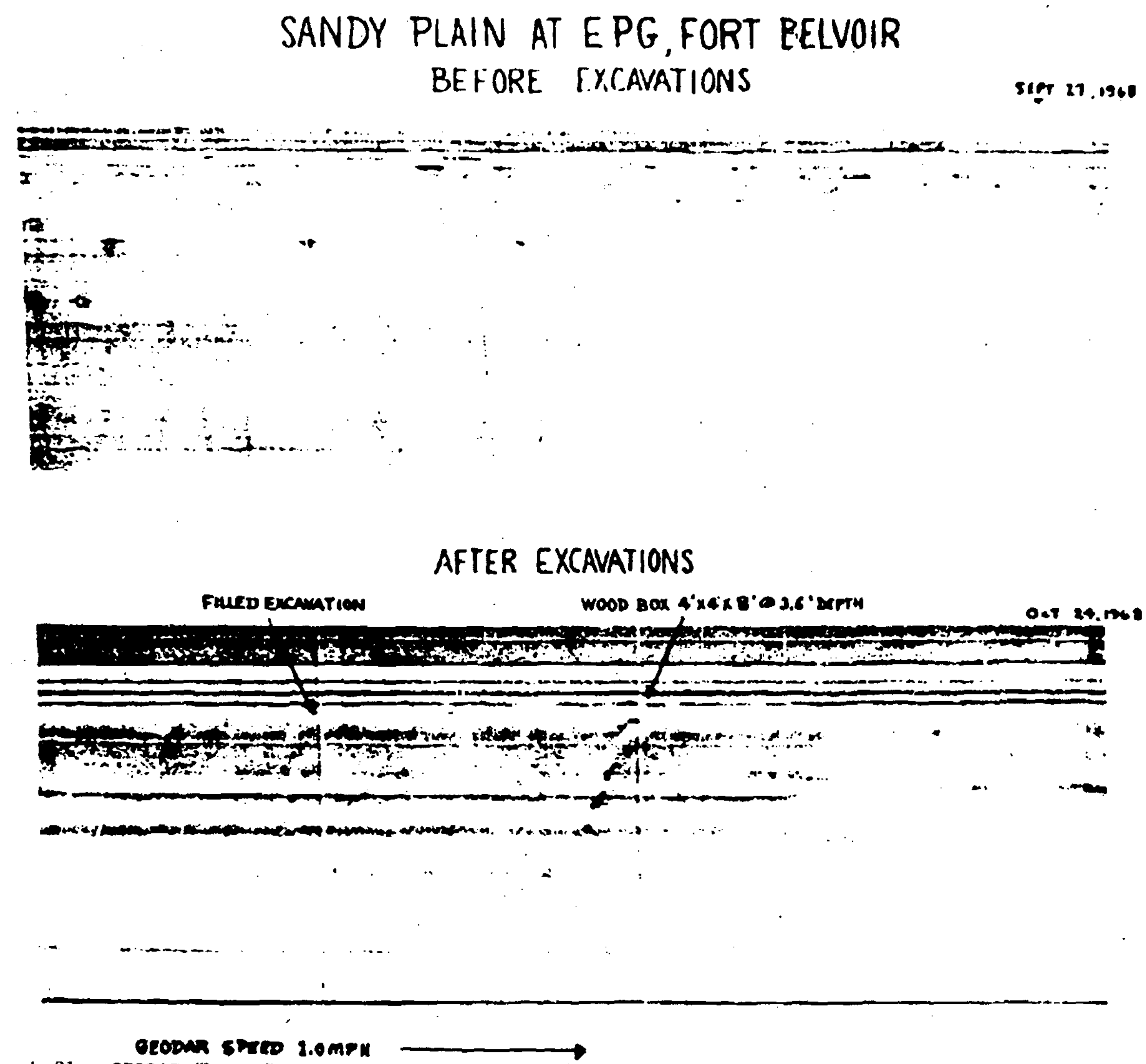
(U) *Another project in tunnel detection at MERDC is the evaluation* of the GEODAR system designed by MIT and produced by Sylvania. This system, like the MERDC electromagnetic detector is essentially a short pulse earth penetrating radar. Unlike the MERDC system, the GEODAR is intended for vehicle use. Photograph nineteen shows the GEODAR system mounted on a jeep and undergoing tests at Fort Belvoir.

(C) The MERDC evaluation plan is intended to determine the detection capability and false alarm susceptibility of the Geodar system. Extensive tests are planned over tunnel and nontunnel areas under various soil and terrain conditions. Initial efforts to detect the shallow tunnel at the Fort Belvoir complex were unsuccessful. Consequently, a clean test site was selected as shown in photograph twenty, and two identical excavations were made. One excavation was completely refilled with soil. The other was equipped with a 3 foot square by 8 foot long wooden box and then refilled. Pre-excavation and post excavation passes were made with the GEODAR. Chart recordings of these passes are shown in photograph twentyone. The chart before excavation is very clean. In the post excavation chart the excavation with the cavity is apparent while there is little disturbance from the refilled excavation. This test clearly proves the detection of a subsurface cavity with an overburden of about 5 feet. Other tests have been made over culverts, the Fort Belvoir tunnel, and along roadways without tunnels or culverts. Photograph twenty-two shows the chart recording obtained by making a pass along a dirt road which contained a metal





Photograph 20: - Controlled Tunnel Test Site at Fort Belvoir



Photograph 21 - GEODAR Chart Recordings over Controlled Tunnel Test Area

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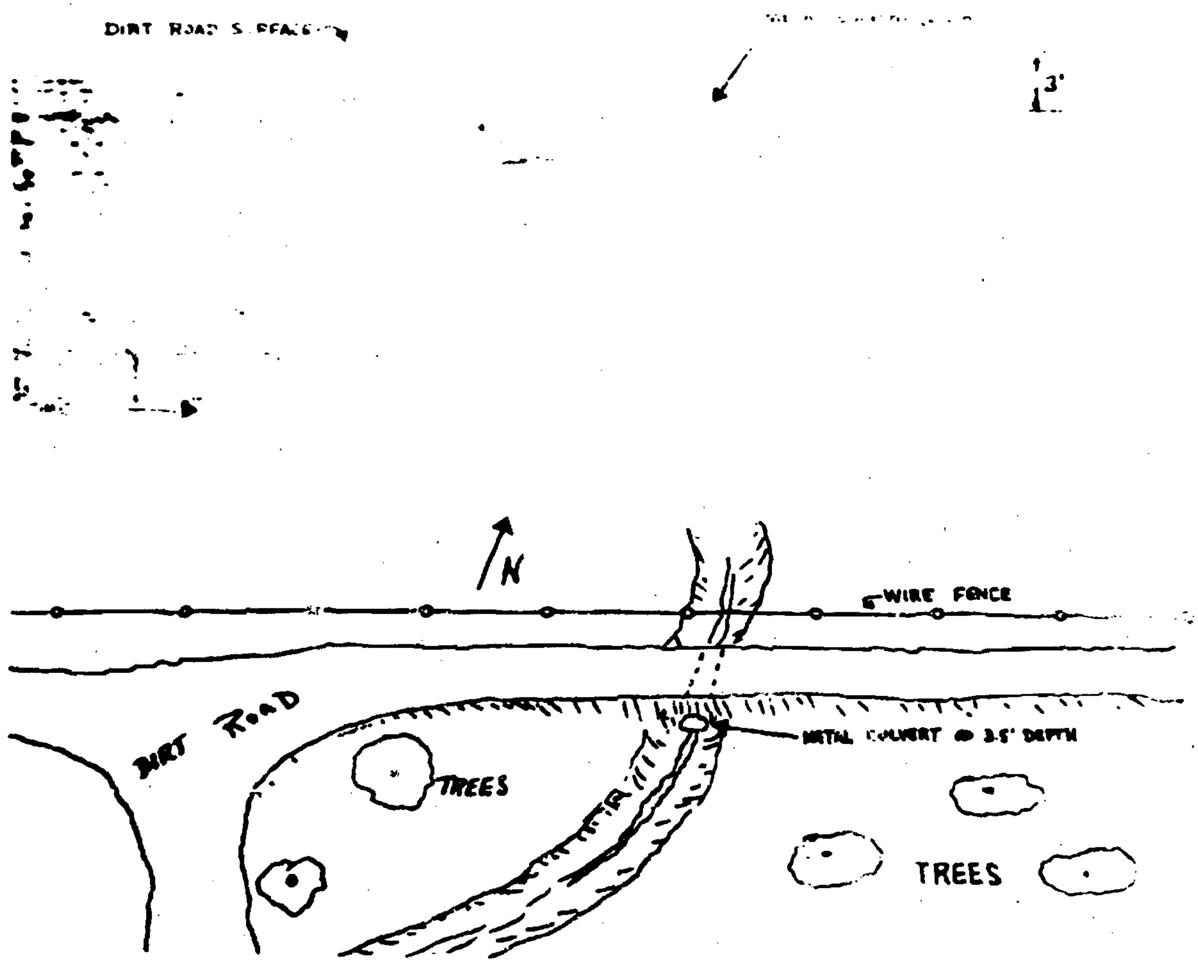


Photograph 22 - GPR Chart Recording Over Dirt Road with Metal Culvert

culvert at a depth of approximately 3 feet. The culvert is apparent, and the other disturbances were found to be trees along side the road. Photograph twenty-three shows the chart obtained when the GEODAR antenna was passed over the shallow tunnel at Fort Belovir. The tunnel is approximately 6 feet deep in the area where the GEODAR was used, and medium sized pine trees cover the tunnel area. From this chart the tunnel cannot be recognized since the characteristic hook shaped pattern does not appear. Photograph twenty-four shows the chart produced when the system is towed along a smooth surface, blacktop road. No culverts or cavities were present in the section of the chart shown here. Trees overhanging the road at a height of 15 to 20 feet produced the patterns seen at various positions.

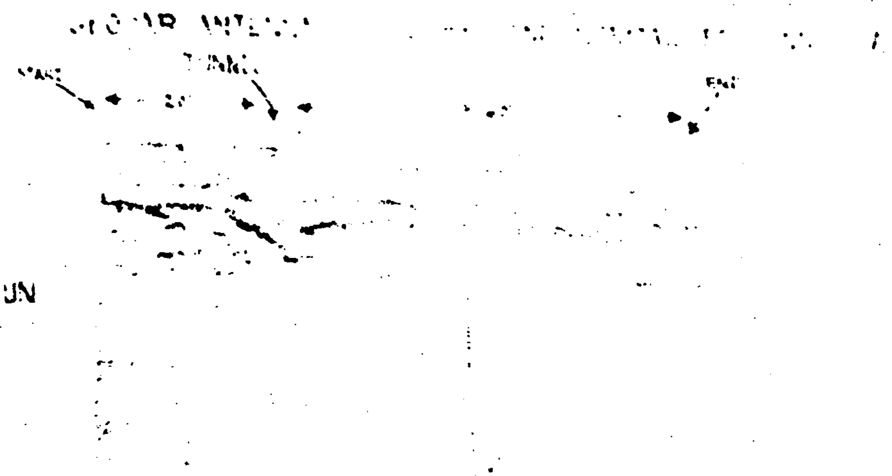
(U) Evaluation of the GEODAR will continue at other tunnel sites of varying soil characteristics. These sites will include areas of Virginia, North Carolina, and Texas. The evaluation will be completed and a report will be published in December if no significant failures occur. The only failures thus far in the evaluation were a power switching relay and a malfunction in the Alden recorder. These were minor failures and Sylvania responded quickly in repairing both the relay and the recorder.

(U) The availability schedule of detectors currently under development and the completion schedule of the GEODAR evaluation are shown in photograph twenty-five.

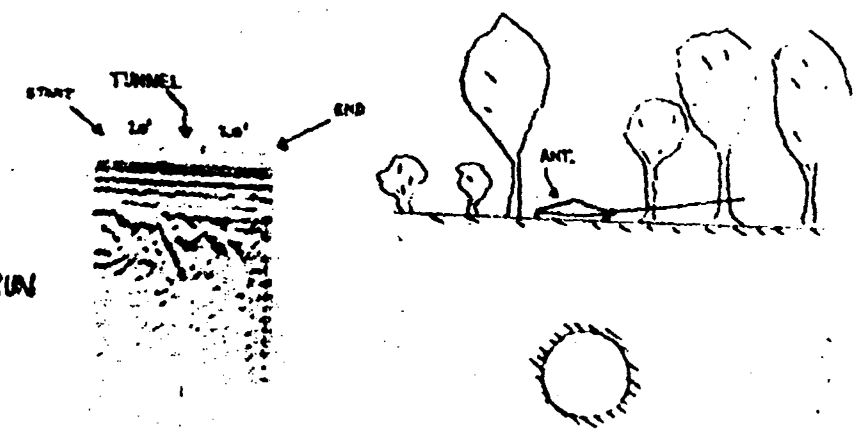
3. (C) Experience of NET Team with Seismic Detector (CPT Hatfield)

(U) I am the chief of the NET Team which will soon be taking the Seismic Tunnel Detector to Vietnam for further evaluation of the equipment

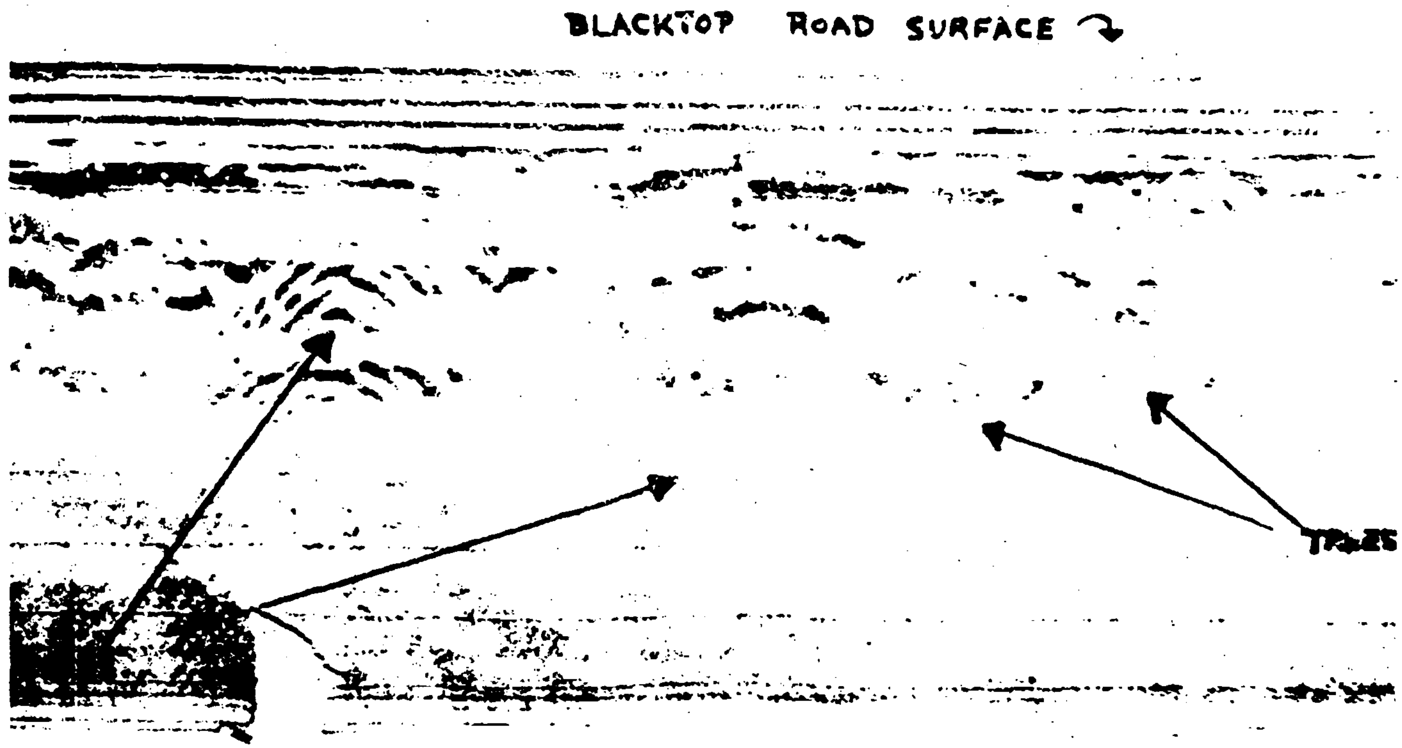
1ST RUN



2ND RUN



Photograph 23 - GEODAR Chart Recording Over Fort Belvoir Tunnel Complex



Photograph 24 INFLUENCE TREES HAVE ON THE GEODAR SYSTEM

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SCHEDULE OF FUTURE TUNNEL DETECTION ACTIVITIES AT MERDC

1. Resubmission of four (4) seismic detectors to Vietnam	Nov. '68
2. Submission of electromagnetic detector to Vietnam	Dec. '68
3. Submission of four additional seismic detectors to Vietnam	Dec. '68
4. Completion of GEODAR Evaluation	Dec. '68
5. Submission of advanced model E-M detector to Vietnam	Feb. '69
6. Establishment of Research Task	Jan. '69

Photograph 25

~~CONFIDENTIAL~~

and the training of in-country personnel. I have been working with this detector for about two months and based on my experiences I will briefly describe its operation to you.

(U) In photograph twenty-six you see the system being transported by two men. Inside the electronics package we have space to carry the receiver, cables, and viewing hood. The transmitter is carried separately. Not shown in this picture is the receiver implanting device which you will see in the next photograph.

~~(C)~~ Photograph twenty-seven shows the equipment being operated by three men, the desirable number for optimum speed of operation. The individuals with the receiver and transmitter couple these items to the ground under the direction of the operator who is carrying the electronics package. The operator then activates the transmitter and views the received seismic pulse on the CRT. The system is capable of two modes of operation, a refractive-like mode and a pulse-echo mode. In the refractive-like mode we detect an increase in velocity and amplitude of the received seismic signal which occurs in the immediate vicinity over a tunnel. I consider this mode of operation to be the one most generally usable and reliable. When utilizing this mode, the operator adjusts the CRT scale settings to allow him to read the travel time of the seismic signal from transmitter to receiver. As the ground is traversed, a noticable decrease in travel time, usually, but not always, accompanied by an increase in signal amplitude, indicates the presence of a tunnel. Points yielding positive readings are marked and their relative locations analyzed for a linear correlation which indicates the presence of a tunnel.

Photograph 26 - Modified Seismic Tunnel Detector During Transport

Photograph 27 - Modified Seismic Tunnel Detector During Operation

(U) On photograph 28 you see the sample wave forms observed by an operator as a run was made over a 4.5 foot deep tunnel. You can see that the travel time decrease is readily apparent.

4. ~~(C)~~ Research Program:

(U) USAMC has been directed by DA to establish a Tunnel Detection Research Task as part of the Barrier-Counterbarrier Project. Technical Committee action is scheduled for January 1969. The Research and Technology Resume, DD Form 1498 as submitted by MERDC is presented as inclosure.

~~(C)~~ The following efforts are planned to be initiated immediately after authorization:

(a) Development of method of soil classification by electrical parameters.

(b) Investigations toward remote detection of tunnels using radar techniques.

(c) Establishment of tropical tunnel test site.

(d) Measurement of scattering properties of voids in a lossy half-space.

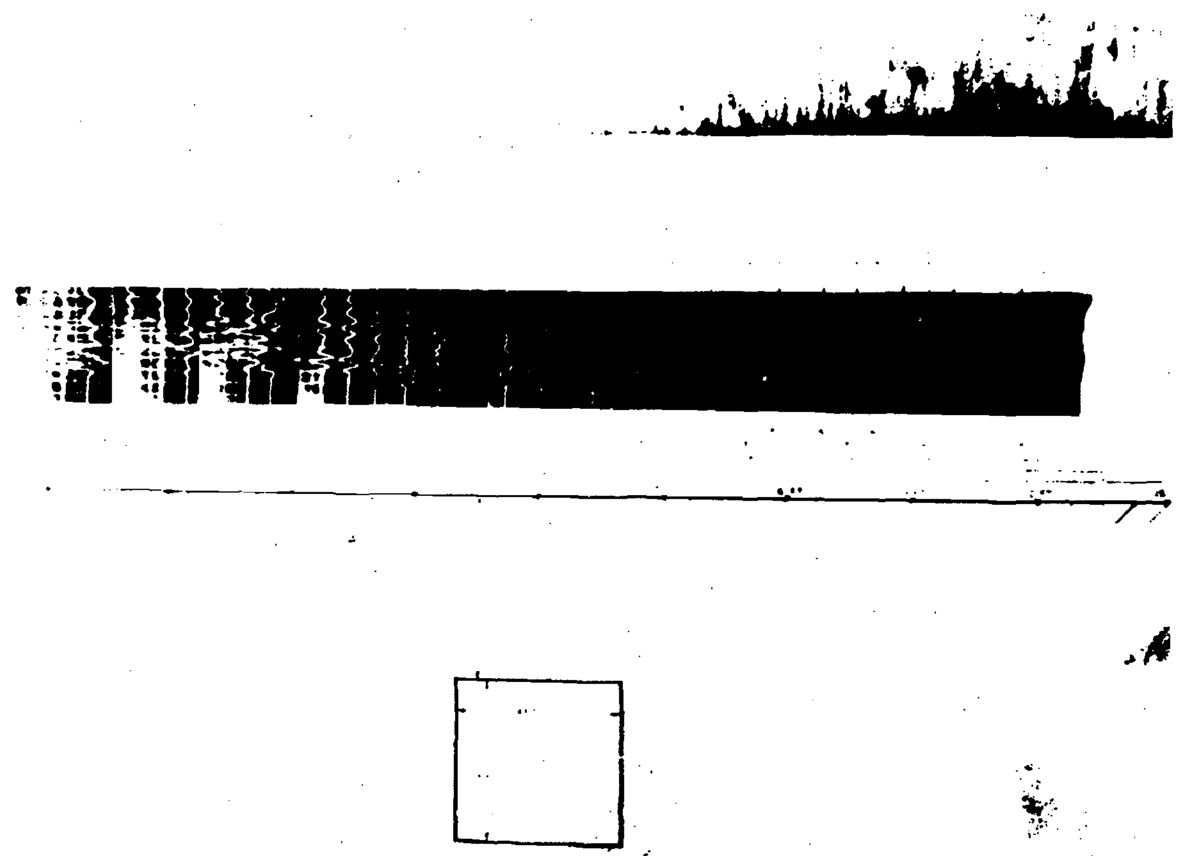
(e) Investigations of seismic techniques for the remote detection of tunnels.

(f) Investigation of electric and magnetic induction field anomalies caused by tunnels and natural geological features.

(g) Exploration of Tunnel Trace Gas Detection techniques.

(h) Investigation of aerosol subsurface trace elements emanating from tunnels.

(i) Investigation of characteristic properties of tunnel spoil.



Photograph 23 - Wave-forms Produced by Seismic Tunnel Detector

U. S. Army Limited War Laboratory
Aberdeen Proving Ground, Maryland

Tunnel Detection
Tunnel Explorer Locator & Communicator
Canine Detection

TUNNEL DETECTION

Thomas E. Olon

U. S. Army Limited War Laboratory
Aberdeen Proving Ground, Maryland

ABSTRACT

Tunnels produce a magnetic contrast with the local environment. This contrast can vary in magnitude but has a unique characteristic. Tunnels run in straight lines. Employing a total field (scalar field) magnetometer and utilizing the straight-line-correlation signature, tunnels can be traced and/or mapped at a militarily usable and rapid rate in a ground-to-ground search mode. Spurious, local surface anomalies (such as shrapnel) can be discriminated by the ability of the sensor and technique to ascertain the extent of a magnetic anomaly without significantly slowing down the search rate.

* * *

Tunnel Signature

The principal parameters which affect the magnetic signature of a tunnel include the size, configuration, orientation and depth of the tunnel as well as the magnetic susceptibility and noise distribution of the soil. Ordinarily, the inclination or dip angle of the earth's magnetic field would be a parameter of interest. However, since the dip angle in Southeast Asia is zero, we will ignore dip angle effects.

The initial phase of the U. S. Army Limited War Laboratory Tunnel Detection Program included a computer analysis of a tunnel considered as a cause of a magnetic anomaly. The computer program was based upon an expression which relates the change in total intensity over a plane surface from a prismatic source of a given susceptibility, inducing field, inclination of field, direction of remanent vector, with the number, location, and coordinates of prisms constituting the entire source. The following 2 charts show some results obtained from this computer modeling.

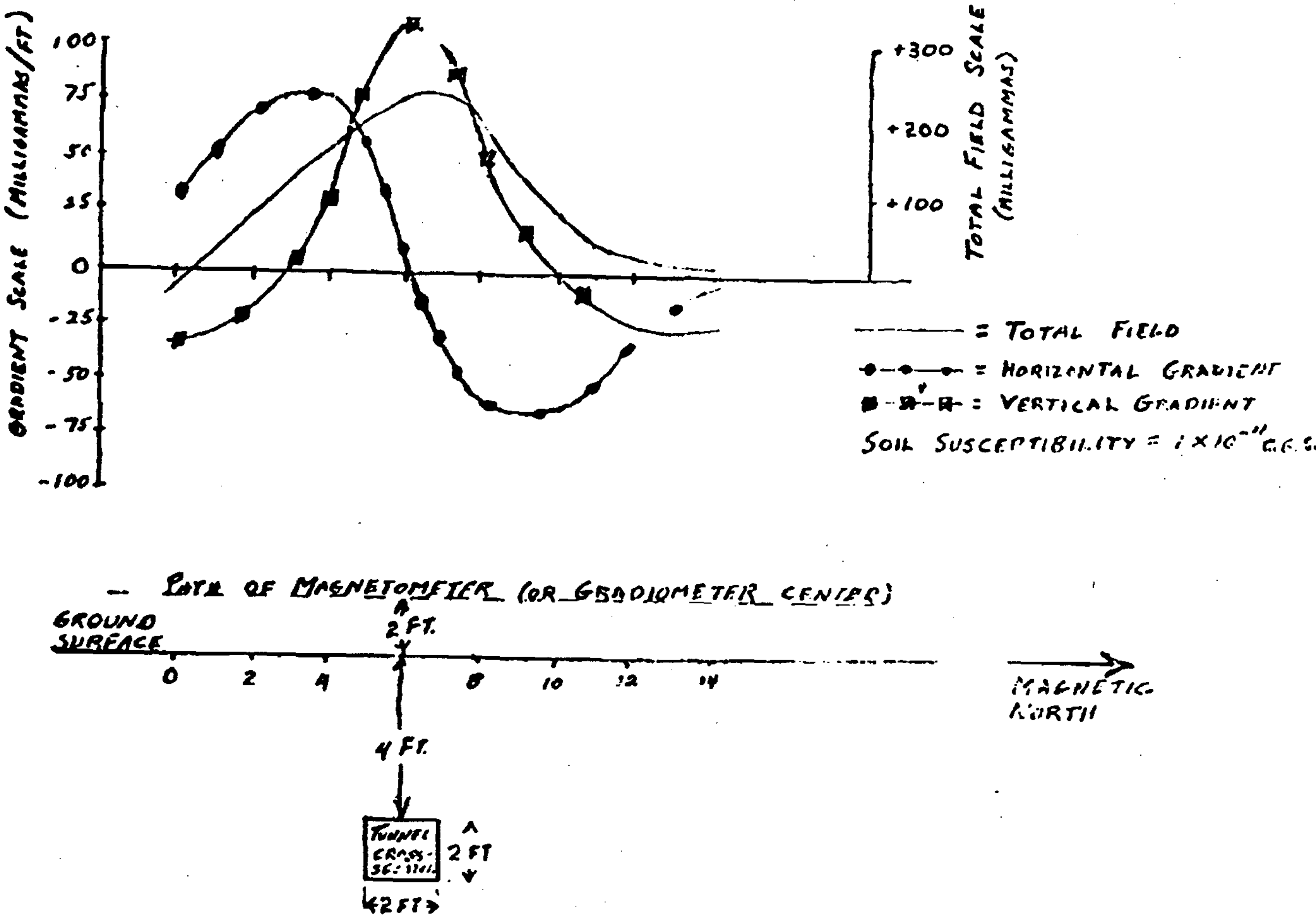


FIGURE 1 . TOTAL FIELD + GRADIENT PROFILES OVER TUNNEL

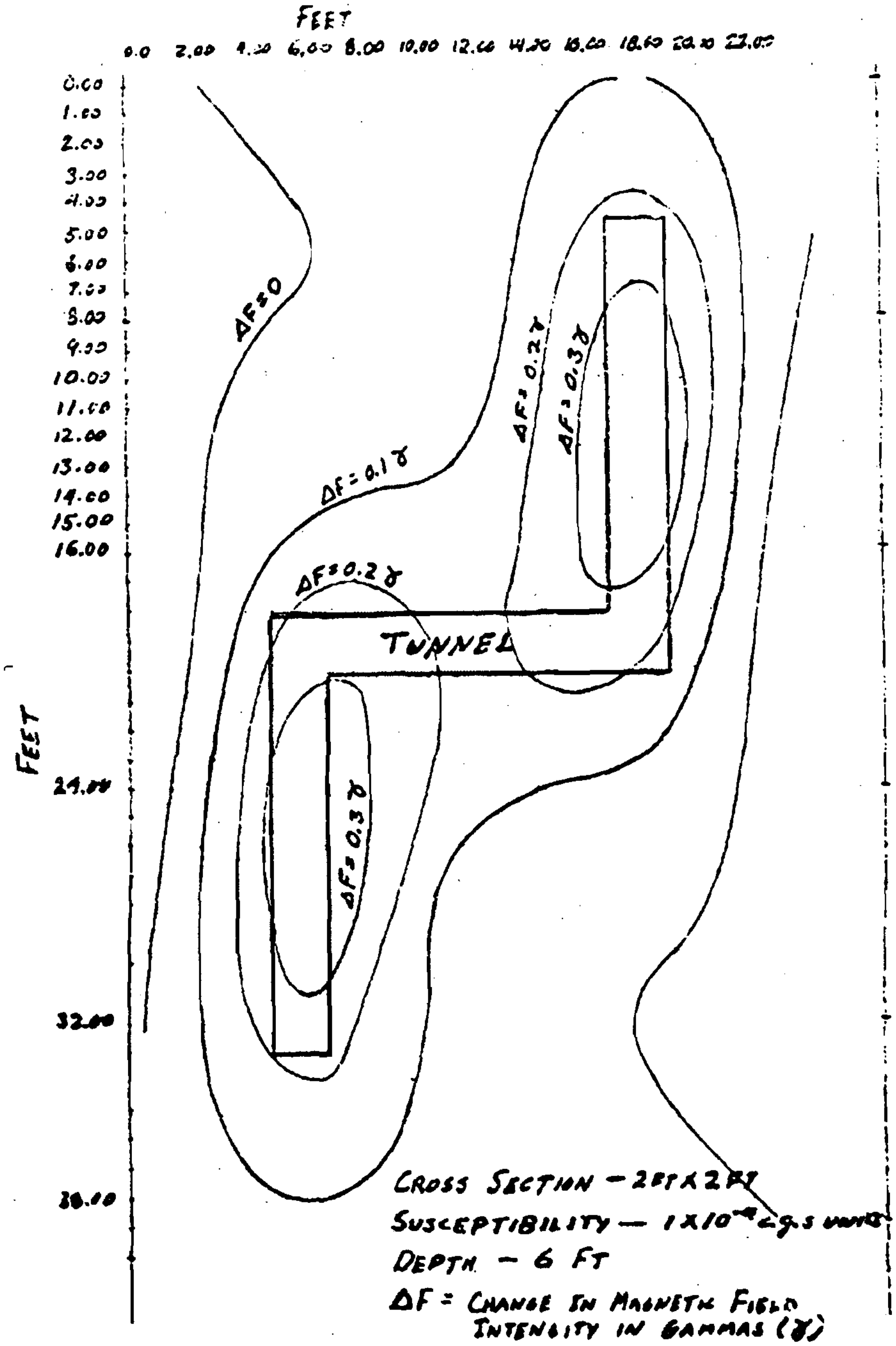


FIGURE 2. MAGNETIC FIELD INTENSITY CONTOURS OVER TUNNELS

There are occasions when one wishes to calculate analytically the anomaly from a tunnel at a given depth, susceptibility contrast, etc. A short method of computing the maximum value of the anomaly can be derived by assuming the tunnel to be of infinite length with a cross-sectional which is small compared with depth, and the axis of which is in an east-west orientation. These requirements (with the exception of the east-west orientation) are met fairly well in most tunnel configurations which are being considered. The anomaly from a tunnel in low magnetic latitudes can then be expressed as

$$\Delta F = \frac{kFA}{r^2}$$

where

k = magnetic susceptibility of the surrounding soil in c.g.s. units

r = the distance from the sensor to the center of the cross-sectional in centimeters, feet or meters

A = cross-sectional area in units consistent with the units of r

F = ambient (inducing) field intensity in gammas

ΔF = maximum value of the magnetic anomaly in gammas

Reports concerning tunnels in Vietnam indicate that most tunnels are two to three meters below the surface and have cross-sectional areas from 4 to 6 square feet and that the earth's magnetic field intensity in this area is approximately 41,000 gammas. These parameters are relatively constant when compared with such parameters as orientation, soil magnetic susceptibility, and background noise.

The orientation of the tunnel axis relative to the earth's field influences the magnitude of the tunnel anomaly as a cosine function. Maximum amplitude occurs when the tunnel axis is perpendicular to the earth's magnetic field vector. An amplitude minima occurs when the tunnel axis is in a north-south direction.

Of equal or more importance than the tunnel axis orientation, is the soil magnetic susceptibility. There are two additive components of magnetic susceptibility--that which relates induced magnetism to the inducing magnetic field and that which accounts for the remanent or permanent magnetism in the soil. Tests have shown that the remanent component is nearly equal to the induced component in soil near the earth's surface. However, at depths of several feet, the remanent/induced ratio decreases to approximately 0.2. The overall significance of the remanent component is that it can enhance the tunnel anomaly amplitude by a factor of 2 to 1. In other sources related to this subject, this effect has not been considered.

The most significant aspect of magnetic susceptibility is its relationship with various soil types. Since the tunnel anomaly is directly proportional to magnetic susceptibility which varies with the soil type, the tunnel anomaly will vary in amplitude depending upon the soil type in which it is located. Reports such as those written by the Military Research and Development Center, Bangkok, relative to magnetometer measurements in Thailand indicate the susceptibility levels range from 1×10^{-5} to 4×10^{-3} c.g.s. units. Studies performed under the Tunnel Detection program indicate the most of this range is favorable for tunnel detection.

Background magnetic noise limits the overall system sensitivity. This noise is due to surface irregularities, short span differences in susceptibilities, man-made objects and micropulsations of earth's magnetic field. All noise is spatial in nature except the last which is temporal. Spatial soil noise varies from milligammas to gammas with soil type. Temporal variations fall within the same range. The spatial extent of most noise is small relative to that of the tunnel anomaly and provides a basis for discrimination. Temporal variations can be effectively suppressed through use of differential magnetometers or gradiometers.

Tunnel Detection and Tracing Techniques

Straight line correlation and variable height sensing are the two basic techniques used when detecting or tracing tunnels with magnetometers. Straight line correlation is a technique which is based upon the premise that tunnels run in straight lines for distances of at least ten meters. Consequently, if this premise is correct, it is reasonable to expect the tunnel magnetic anomaly to be somewhat long and narrow. Thus a basis for discrimination between the tunnel anomaly and the magnetic background has been established.

The other technique of variable height sensing consists of raising the sensor in the presence of considerable surface or near-surface anomalies and lowering the sensor in their absence. Surface or near-surface anomalies have an inverse cube dependence while that of the tunnel is inverse square dependent. Therefore, within the limit of sensitivity of the magnetometer, this technique will improve the signal-to-noise ratio.

Description of the Magnetometer System

Functional Description:

The magnetometer system includes the sensors, sensor electronics, sensor staff, audio readout, a rechargeable battery, and battery pack with harness. Other parts include the accessories and the carrying case. The system characteristics are:

Sensitivity	- 0.025 gammas/ft (differential mode) 0.1 gamma (single sensor mode)
Range	- 30,000 to 70,000 gammas
Staff length	- Approximately 8 ft.
Battery life/charge	- 8 hour continuous
Weight:	
In operation	- Less than 20 lbs.
In storage	- Less than 50 lbs (includes spare battery pack and accessories)
Accessories	- Battery charger, earphones, and miscellaneous spare parts
Size	- Approximately 6.5 cu. ft. (storage)

Uses and Features

The differential mode was designed primarily for detecting tunnels while the single sensor mode is more suitable for tracing them. Figure 3 shows the magnetometer system in operation. When used differentially, the eight-foot spacing between the two sensors provides spatial filtering which enhances the spatial wavelength generally associated with most tunnels. Moreover, time variations of the earth's magnetic field intensity are effectively eliminated since these variations are common to both sensors. These features, together with electronic filtering, make possible a higher signal-to-noise ratio in this mode. However, since in the differential mode a quasi-gradient is measured (a true gradient would be measured if the sensors were closely spaced), large background magnetic gradients can lower the signal-to-noise ratio.

The effects of background gradients are suppressed by use of the prescribed tunnel detection techniques. When it is required that a large area be checked, either of the following procedures can be used.

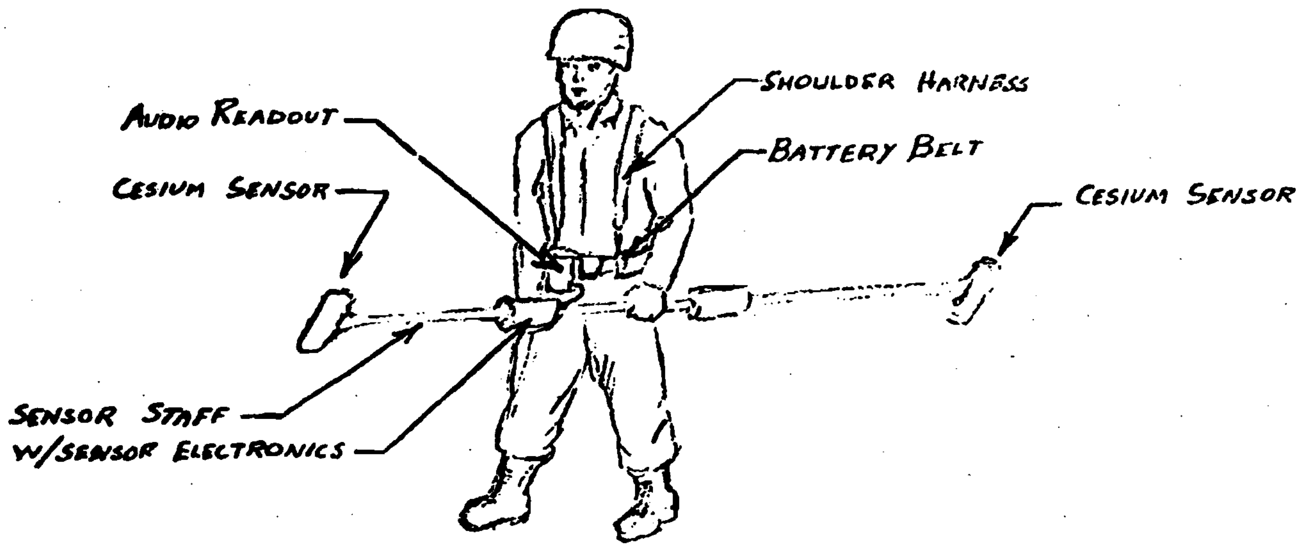


FIGURE 3. MAGNETOMETER SYSTEM IN OPERATION

(1) Lay out the area in grid squares and record readings at each of the grid corners. Then examine readings, checking for straight lines formed by similar magnetic anomaly amplitudes.

(2) Traverse the area in a series of parallel paths with attention given only to those anomalies with a typical tunnel signature. If such an anomaly is found, check area in close proximity for straight line formations. Then trace tunnel or continue search as necessary.

Using these procedures, the sensor staff is kept in one direction and the background gradient effect is somewhat constant, thus presenting itself as an offset which can be ignored.

The single sensor mode is best suited for tracing tunnels after the tunnel mouth or any other portion of the tunnel has been detected. The tracing operation is accomplished by swinging the magnetometer in a wide arc and then moving in a direction which will keep the tunnel anomaly within the limits of the arc. When the operator does this, he will be walking directly above the axis of the tunnel.

Twelve differential magnetometer systems will be fabricated and tested in CONUS by the 3rd quarter of FY 69. Additional tunnels have been constructed in California and will be used for the CONUS test. Start of a Vietnam evaluation of ten of these systems is scheduled for 3rd quarter of FY 69.

TUNNEL EXPLORER LOCATOR & COMMUNICATOR

Thomas E. Olon

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The Tunnel Explorer Equipment enables two-way voice or tone communication between personnel exploring tunnels underground and personnel on the surface of the ground, with an effective slant range of approximately 120 feet. Voice mode of transmission enables the underground personnel to describe their surroundings to those on the surface; the surface personnel can also describe surface activities and relay orders. Tone transmission is an 1100 Hertz intermittent signal which, when used by the underground personnel, permits the mapping of the tunnel; this is accomplished by ground personnel walking along the surface and DF'ing (direction finding) on the man in the tunnel. Automatic gain control circuits are incorporated in both the transmitting and receiving circuitry so that operation of the equipment can be accomplished over a wide range without constant adjustment of the gain control.

The Tunnel Explorer equipment consists of two identically assembled units each consisting of an antenna, transceiver, and an interconnection cable. Each unit is designed to be carried on the back and left front shoulder of an individual using the standard soldier's field suspender harness. The use of the harness offers freedom of hand movement, except to operate a function switch on the front panel of the transceiver. The Tunnel Explorer equipment is waterproof and shockproof under normal handling conditions, and is painted olive drab to blend in with the soldier's military dress. Each complete unit weighs approximately 4 pounds.

a. The antenna is a formed ring approximately 13 inches in diameter, containing two sets of antenna windings, a transmitter and a receiver winding. The transmitter antenna consists of 58 turns of number 20 copper wire; the receive antenna consists of 1250 turns of number 34 copper wire. The antenna windings are encased in a 1-inch-square hoop of polyurethane, which holds the coil rigid and maintains a waterproof and shock resistant housing. Molded into the polyurethane are three metal loops through which straps are threaded for attaching the antenna to the field harness, and a connector jack to which the four antenna leads are connected. Two of the metal loops are positioned at the top of the antenna hoop, spaced apart by 60 degrees, and are used to attach the antenna with adjustable straps to the shoulder loops on the field harness. A single bottom metal loop is positioned

180 degrees from the center position of the two shoulder loops and is used to attach, with an adjustable strap terminated with a wire clip, to an eyelet in the soldier's pistol belt. Offset by 20 degrees to the right of the bottom metal loop is a jack to which the interconnection cable is attached. Velcro nylon tape is used as the adjustable straps for attaching the antenna to the field harness. This tape consists of two strips of nylon which when pressed together lock and hold firmly against any vertical tension, but easily separate when horizontal tension is applied with respect to the facing leaf.

b. The transceiver is a self-contained battery-powered transmitter and receiver, which contains two replaceable edge-connector printed circuit card assemblies. The card assemblies use discrete and integrated components employing analog type electronic circuitry. The transceiver unit is enclosed in a waterproof, shock resistant, plastic case with an aluminum front panel. The panel is held in place by four captive screws, which are loosened for the removal of the panel and the two card assemblies. A retaining cord prevents damage to any connecting wires when the front panel is removed. A magnetic transducer sealed in a circular mu-metal housing serves both as microphone and speaker. A special membrane covers the transducer to prevent damage should the instrument be immersed in water. A front panel jack enables the connection of the transceiver to the antenna. The transceiver is connected to the left front strap of the field harness using Velcro nylon tape, which is also threaded through plastic loops on the bottom of the transceiver. Plastic leafs projecting beyond the front panel protect the control knobs from damage should the instrument accidentally drop.

c. The interconnecting cable, which electrically connects the transceiver to the antenna, is a four conductor cable with 90 degree connectors on each end. The cable, approximately 3 feet long, lies on the left shoulder and connects the antenna jack to the jack on the front panel of the transceiver.

Ten systems, plus spares, are being fabricated. Delivery to LWL is expected in a few weeks and we hope to ship to VN this December.

TABLE 1-1. LEADING PARTICULARS AND SPECIFICATIONS

TITLE	SPECIFICATION
DIMENSIONS:	
Antenna	12.82 inches (outside diameter)
Cable, Interconnection	3 feet (approx), 4 conductor
Transceiver	
Height	2.40 inches (overall)
Width	6.72 inches (overall)
Depth	4.37 inches (overall
WEIGHT:	
Antenna	2.0 pounds (approx)
Cable, Interconnection	0.3 pounds (approx)
Transceiver	1.62 pounds
TOTAL WEIGHT:	≈ 5 pounds (including equipment case)
POWER REQUIREMENTS:	5 mercury-cell batteries, 2.6 volts each, type BA 1373/U.
OPERATION AND RANGE:	Voice or audio signal communications from underground-to-surface at a slant range of 120 feet.
VENTILATION:	None
DUTY:	Continuous
FREQUENCY CHARACTERISTICS:	Audio range - voice frequencies and an 1100 Hertz signal.

TABLE 1-1. LEADING PARTICULARS AND SPECIFICATIONS (CONT)

TITLE	SPECIFICATION
EQUIPMENT ENVIRONMENT:	Waterproof and shock resistant
CLIMATIC CHARACTERISTICS	
Ambient Temperature	+40°F to 160°F (+4.4°C to + 71°C)
Relative Humidity	Up to 100% throughout ambient temperature
TRANSPORTABILITY:	Transportable in any standard air or ground conveyance. The equipment may be shipped in its own fiberglass container or packaged as desired.
STORAGE:	The equipment can be safely stored in any position in its equipment case.

CANINE DETECTION OF TUNNELS

MAJ Joseph Lenoci

USALWL Task 01-B-68, Canine Detection of Tunnels is a one year effort to train two squads (14 dogs) of an Infantry Platoon Scout Dog, to detect tunnels. This task has been active since January 1968.

This year is broken down into two six-month phases. Phase I was devoted to studying, researching and trying several training methods to develop the most effective and efficient training program. The objective of Phase II is to train one-half of a TO&E scout dog platoon in tunnel detection. The other half of the platoon is being trained under a parallel effort to detect booby traps, trip wires and mines.

The simulated training tunnels used in this program are ground cavities 36" x 18", or larger, that are vented or open to the atmosphere.

The procedure used is to have the dog work off-leash, being directed by arm and hand signals from the handler. The handler works the dog in a criss-cross pattern over the search area, covering a minimum of one acre per hour in wooded terrain. When the dog detects a tunnel he comes to the sit position within two feet of the opening.

At the present time, half way through Phase II, the food reward system is being used for training purposes. This system is used for training only and is not intended to be employed in combat since the number and frequency of finding tunnels cannot be controlled. Thus, prior to RVN evaluation, the dogs will be switched to praise for each find.

Control of the frequency of finding tunnels may present a problem. In order to maintain the dogs at peak proficiency, it may be necessary to periodically bring the dogs back to a base area for a short retraining period. The period between and length of these retraining periods will depend on the individual dog. It is felt that the time frames and methods will be finalized during the RVN evaluation.

Based on available data it is felt that these dogs will be able to work 4 to 6 hours per day looking for tunnels. If more than this is needed, then a team of 2 dogs may be used alternating the dogs on an hourly basis.

The dogs appear to be detecting the tunnels by using olfactory senses. They appear to alert on the air emanating from the opening. At this stage of training, the dogs have been able to detect a high percentage of the training tunnels with a very low rate of false sits. This percentage seems to hold true whether the tunnel is occupied, unoccupied, contains materiel, or is empty.

The results of this program look very promising thus far. However, this is an R&D program and the operational effectiveness of this system will be determined during the RVN evaluation. This system is programed for shipment to RVN for operational evaluation in 3rd Qtr, FY69.

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US Army Waterways Experiment Station
Vicksburg, Mississippi

WES Tunnel Research Projects

Mr. Billy R. Davis

WES TUNNEL RESEARCH PROJECTS

1. Over the past three years the U. S. Army Engineer Waterways Experiment Station (WES) has conducted projects dealing with the following aspects of tunnel research:

a. Mapping tunnel complexes
b. Environmental characterization of tunnel complexes
c. Destruction of tunnel complexes

2. In the area of mapping tunnel complexes, two programs have been conducted as follows:

a. Tunnel Explorer Locator System. In 1967 a WES field party was in Vietnam participating in a program concerned with gathering quantitative measurements of various environmental factors in and around tunnel complexes. In order to perform this mission, it was necessary to explore the interior of the tunnels for the purpose of mapping the tunnel complex and gathering environmental data on the interior. Extreme difficulties were encountered in communicating with personnel inside the complex and in pinpointing their location for purposes of mapping the complex. Information regarding these difficulties was relayed back to the WES to determine whether any assistance could be rendered to solve these problems. Personnel assigned to the Terrain Analysis Branch of the Mobility and Environmental Division evaluated the various possibilities for solution of this problem and within two weeks shipped a modified two-way radio communication system of the walkie-talkie variety to our personnel in Vietnam for use in the tunnel environmental characterization project. The system proved to satisfy the requirements of communicating with and pinpointing the location of tunnel explorers, and additional efforts were expended at the WES to determine the limitations of such a system. In early 1968 the WES received a request from Headquarters, U. S. Army Vietnam, to supply six prototype systems for use in Vietnam. The final WES version of the system (see fig. 1) is now being evaluated in Vietnam by the Engineer Command, and thus far all reports that we have received have been favorable. Unfortunately, however, we understand that the system is being used primarily for communication purposes, and the system's capabilities for pinpointing the location of personnel assigned the task of exploring tunnel complexes are not being utilized to the fullest extent. This is regrettable because if communication capabilities are the only interest of the military forces, the system can be reduced in size considerably. The WES does not plan to do any further work along the lines of refining this system unless requested to do so by a higher headquarters. We feel that ECOM or some other Government laboratory that normally does work of this nature should take the results of the Engineer Command's evaluation, miniaturize the system wherever possible, and come out with a final design that is rugged enough for military use. Our interest was and still is limited to the concept used and not the actual hardware involved.

b. Airborne VHF Mapping. Approximately three years ago MERDC presented to the scientific community the overall problem of detecting tunnels and requested that organizations interested in performing research submit proposals. Personnel at the WES assigned to the Terrain Analysis Branch reviewed the capabilities of various sensing techniques and concluded that there was no quick solution to the problem. Groundborne systems were not considered desirable because of the extensive time required to survey the large areas involved. The only remote sensor that appeared feasible was an airborne VHF mapping system. Such a system, however, could not be assembled overnight, and the possibilities of developing a suitable system for use in Vietnam were not considered favorable. Information obtained from military intelligence, however, indicated that U. S. Forces can expect to encounter tunnels in future conflicts, and the WES submitted a proposal to MERDC for development of an airborne VHF system realizing that it probably would not be available in time for use in the Vietnam war. The proposal was rejected by MERDC; however, since tunnel detection consists of detecting local nonhomogeneities in the soil, and because the Corps of Engineers has a continuing interest in any device which holds promise of detecting subsurface variations in engineering properties of soils or rocks, funds were provided by the WES Director for conduct of a scale-model study to verify the feasibility of such a system. These inhouse studies were conducted in 1966 and the results are reported in WES Technical Report No. 3-769, "Feasibility Study of the Use of Very High Frequency Radio Imaging Techniques for Detection of Tunnels (U)." The scale-model study indicated that the system is potentially capable of identifying changes in soil and rock properties and detecting subsurface cavities. Accordingly, funds were then provided by AMC for conduct of Phase I of a development program which covered further theoretical feasibility studies and design of a groundborne system for use in Phase II of the program . Phase I was conducted jointly by the WES and Goodyear Aerospace Corporation, and a report is now being written on the results of this phase of the study. Approximately $200,000 has been requested for conduct of Phase II. In the Phase II portion of the development program, a groundborne VHF mapping system will be evaluated to determine the capabilities of VHF mapping techniques for detecting subsurface openings. Funds have not yet been provided to cover the Phase II portion of the program, which will require approximately nine to twelve months to complete. If Phase II of the program should indicate that such a system is still feasible, Phase III which involves the design and development of an airborne system would be undertaken.

3. In the area of environmental characterization of tunnel complexes, the WES has been involved in two projects as follows:

a. In early 1967 ARPA provided funds to gather quantitative measurements of various environmental factors in and around tunnel complexes in Vietnam for guidance in establishing the suitability or the sensitivity requirements of various experimental or hypothetical sensor systems. Such factors as tunnel geometry, surface composition, soil surface temperature, temperature and humidity profiles inside tunnels, at tunnel openings, and above tunnel openings; air flow through the interior of the tunnel complexes, vegetation, and visual appearance and reflectivity were examined. The results of this data collection program are reported in WES Miscellaneous Paper No. 4-919, "Environmental Characteristics of Tunnels in South Vietnam."

b. In the last quarter of FY 68, MERDC transferred funds to the WES to participate in another tunnel project. This project deals with gathering additional environmental data on tunnels in Vietnam to support tunnel detection research. The data collection program involves using prototype tunnel detection devices developed by MERDC and other special equipment developed by WES or MERDC. The measurements or samples to be collected, equipment to be used, and the parameters to be derived are summarized in table 1. Initiation of the field studies in Vietnam is awaiting approval from the U. S. Army Headquarters, Vietnam. Development of the instrumentation needed to continuously monitor those environmental factors of interest has been completed by the WES. The instrumentation package (see fig. 2) proposed for this use consists of a 12-channel D.C. recorder developed at the WES and sensors capable of continuously monitoring temperature, humidity, and wind velocity.

4. In the area of tunnel destruction, the Nuclear Weapons Effects Division at the WES has participated with the USAMC (Picatinny Arsenal) on a field operation conducted to assess the effectiveness of several gaseous mixtures in demolishing earthen tunnels. These tests were held at the Clark Hill Reservoir in South Carolina in early 1966. Two different gases were used, acetylene and MAPP (methyl acetylene propadiene, and propylene).

a. Seven tunnel complexes were fired on, with entranceways, cache size, depth of overburden and type of gas used being varied.

b. The Department of the Army assigned Picatinny the task of developing a simple, effective method of destroying underground tunnels and caches. Conventional high explosives are not practical, primarily because such explosives would have to be hand-placed at many strategic points inside the tunnels. These heavy charges would have to be carried in and the hazards of completely exploring the tunnels are too great. Charges placed on the surface would be largely ineffective because the tunnel outlines would not be known. An explosive gas, blown in at various tunnel entrances and detonated from the outside, seemed to be the ideal solution.

Picatinny, working with various agencies, determined the two most promising gases, acetylene and MAPP. Acetylene is a widely used gas, whereas MAPP is a more recent development. MAPP is methyl acetylene propadiene and propylene and can be procured commercially. MAPP, when mixed with oxygen and detonated, yields a slightly higher impulsive load than does acetylene. When procured commercially, both gases are contained in heavy tanks and present a handling problem. A gas which could be generated simply and on site would be the perfect solution. Picatinny developed such a solution, a portable acetylene generator (fig. 3). This system consists of a lightweight aluminum mixing tank, water bags, and calcium carbide. Water is poured into the tank, carbide is dumped in, and acetylene is generated instantly. The gas is piped into the tunnels and dispersed with a "Mitey Mite" blower.

d. Table 2 summarizes five of the seven tests conducted. Essentially, the hydrocarbon gases are only effective against overburdens not greater than 6-7 ft.

e. After the tests in South Carolina, it was felt that perhaps scaled tests using model tunnels would shed some light on generalized tunnel failure mechanisms. Such a test program was conducted at Vicksburg.

f. Fig. 4 shows a schematic of the test variables for this program.

g. Primacord (PETN) charges of different quantities were detonated on the bottom of these cylindrical tunnels. The opening of each tunnel was sealed so that the entire effect of the explosion could be contained within the tunnels.

h. The soil here is an extremely strong silty clay of the Vicksburg loess formation. Unconfined shear strength of approximately 5 tons/ft^2 was obtained at a moisture content of approximately 22 percent. Based upon best available data, it is believed that this soil is as strong or stronger than most soils in Vietnam where tunnels have been found. The tests should represent an upper bound for soil strength.

i. After it was determined that the soil was suitable, the site was cleared and grubbed of all overburden and then graded such that vertical shelves of different heights were exposed to facilitate drilling of horizontal, circular tunnels with a skid-mounted drill rig.

Tunnel Dia	Overburden	Charge Density(lb/ft^3)
6 in.	24 in.	.2 - .4
12 in.	48 in.	.2 - .3
18 in.	72 in.	.1 - .2

j. Although considerable damage was done in the form of longitudinal and radial cracking in the soil positive failure did not occur until the 0.35 lb/ft^3 shot for the 5-in. diameter tunnel and 0.30 lb/ft^3 shot in the 12-in. diameter tunnel.

k. It was learned from these tests that for the depth of cover (H) to tunnel diameter (D) ratio of 4, approximately 0.30 lb of prima cord per cubic foot of tunnel volume is needed to destroy the tunnel.

l. Experiments should be conducted with point-source charges and compare results with linear charges of equivalent total explosive. This is recommended because of the belief that, in most tactical situations, point-source or satchel-type charges would be easier to place.

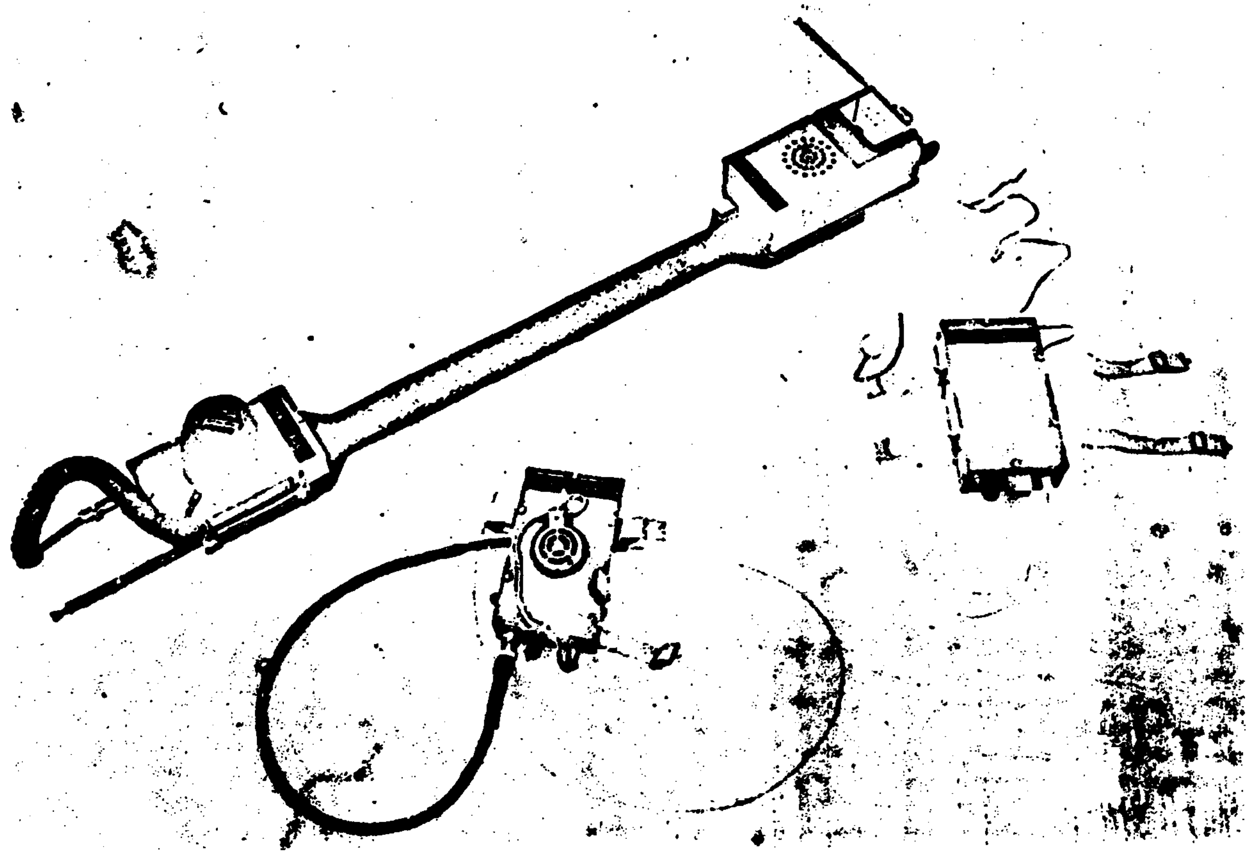


Fig. 1. Tunnel Explorer Locator System

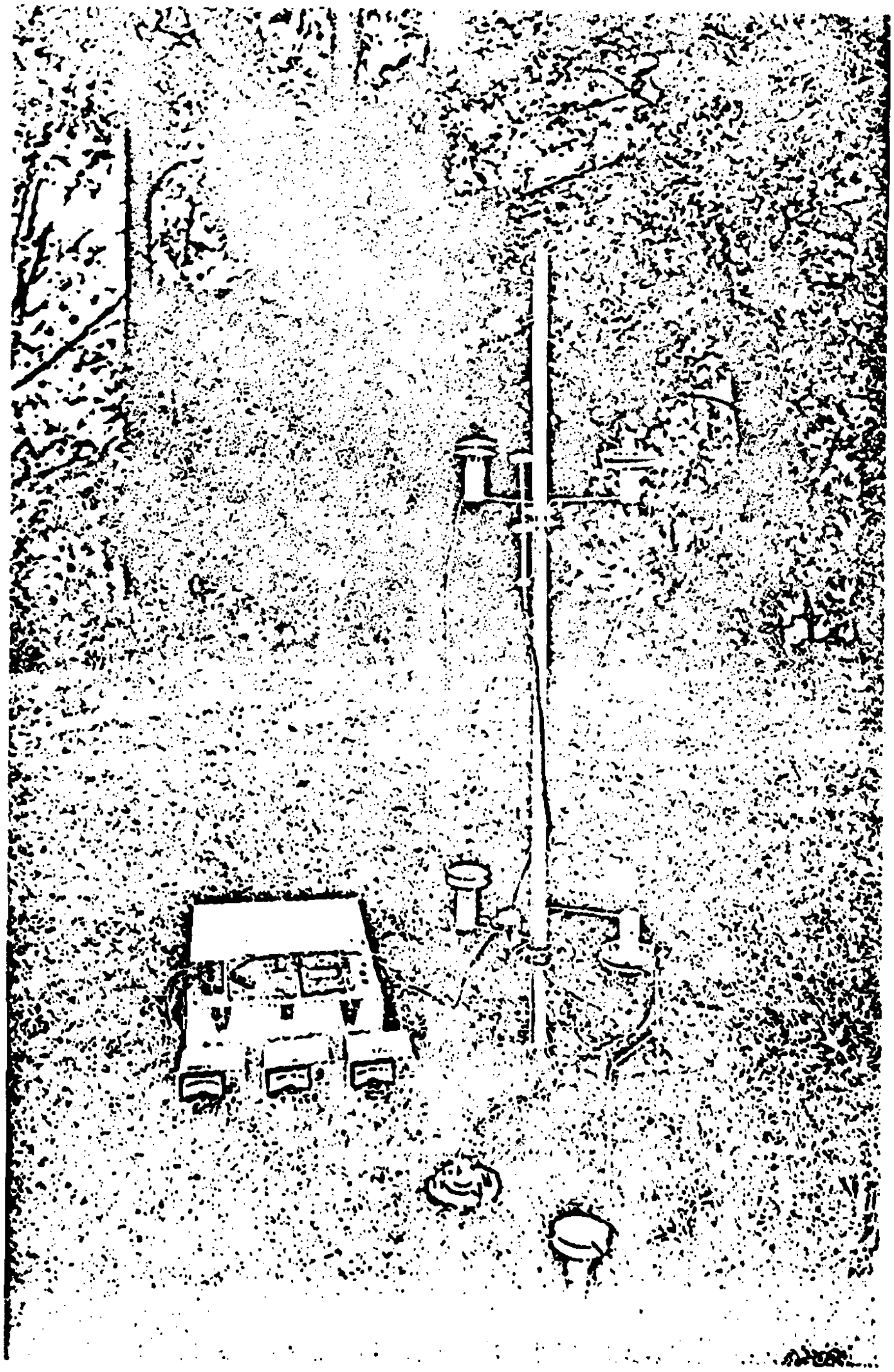


Fig. 2 WET METEOROLOGICAL SYSTEM

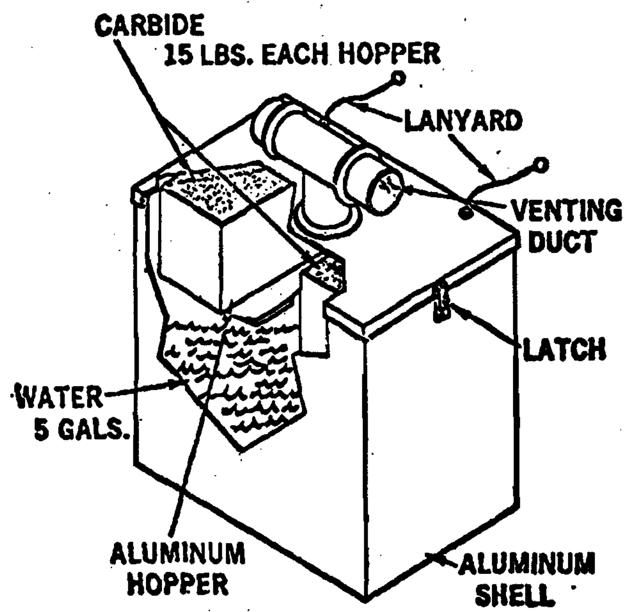


Fig. 3 Acetylene generator: Chemical reaction of calcium carbide and water produces approximately 100 cu ft of acetylene which is introduced into tunnel by means of a flexible hose.

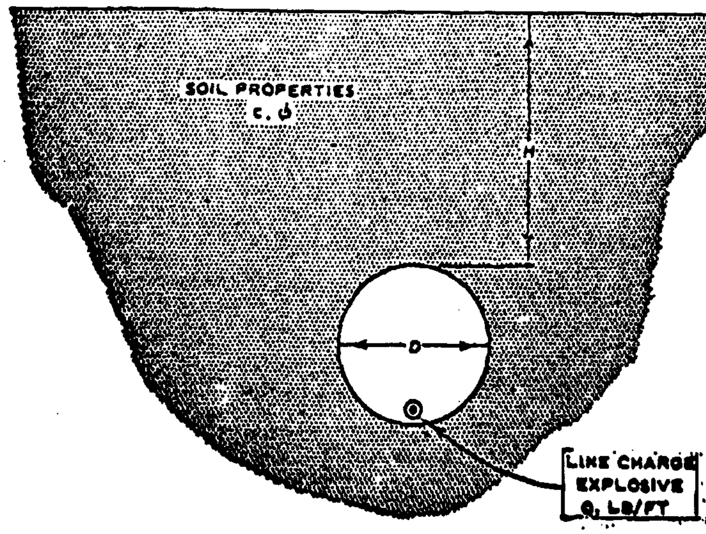


Fig. 4. Tunnel Destruction Test Variables

Table 1

Tunnel Environmental Data Collection Program

Measurements or Sampling	Equipment	Derived Parameters*
Vertical propagation velocity Vertical attenuation Lateral attenuation Media backscatter	Prototype seismic tunnel detector, scope, camera, and adaptor	Short pulse dispersion Tunnel scattering efficiency
Soil profile description Disturbed soil samples, by horizon, 0 to 10 ft	Sampler and soil containers	Particle content versus depth Moisture content versus depth (and as a function of rainfall) Organic matter content versus depth pH factor versus depth Metallic oxide content versus depth Salts content versus depth Density versus depth
Vertical propagation velocity Vertical attenuation Lateral attenuation Media backscatter	Video pulser, antennas, power source, sampling oscilloscope	Short pulse dispersion Tunnel scattering efficiency
Soil profile description Undisturbed soil samples, by horizon, 0 to 10 ft	Sampler and soil container	Conductivity versus frequency Particle content versus depth Moisture content versus depth (and as a function of rainfall) Organic matter content versus depth pH factor versus depth Metallic oxide content versus depth Salts content versus depth Density versus depth
Air samples from unoccupied tunnel Air samples from occupied tunnel Air samples from above disturbed earth in tunnel Air samples from atmosphere around tunnel	Gas absorption bottles and pump	Spectrometric analysis of air sample from unoccupied tunnel Spectrometric analysis of air sample from occupied tunnel Spectrometric analysis of air sample from above disturbed tunnel earth in tunnel versus time Spectrometric analysis of air sample from atmosphere around tunnel
Air flow in unoccupied tunnel Air flow in occupied tunnel	Wind probe	Breathing rate of unoccupied tunnel Breathing rate of occupied tunnel
Air temperature from same points air samples are taken	Temperature sensor	
Air humidity from same points air samples are taken	Humidity sensor	

* Computations and laboratory analysis (except moisture content) of samples will be done in the U. S.

Table 2. Summary of Tunnel Tests in Lean Clay (CL) at Clark Hill Reservoir (U)

Tunnel No.	Explosive Gas	Shot	Soil UC Shear Strength kip/sq ft	Tunnel Cover H, ft	Test Results
1	Acetylene	1	1	5	Failed
		1		8	No failure
		2		8	Fissures on surface
2	Acetylene	1	1	5	Failed
		1		8	No failure
		2		8	Failed
3	Acetylene*	1	1	5	Failed
		1		8	No failure**
4	Ether	1	1	-	Misfire
	MAPP	2		6	Failed
		2		7	Fissured
		2		8	No failure
	Acetylane	3		7	Failed
		3		8	Failed
5	MAPP + O_2	1	1	8	Failed†

* Aluminum powder added.

** 10-ft-wide cache with 8 ft of cover failed.

† 10-ft-wide cache with 10 ft of cover failed.

Oak Ridge National Laboratory
Oak Ridge, Tennessee

Tunnel Detection Experiments

Mr. J. C. Pigg

Classified Document

Filed in

Physical and Engineering Sciences Division

PRECEDING PAGE BLANK-NOT FILMED

The Influence of Electrical Properties of Solid Earth Media on Tunnel Detection by Electromagnetic Methods.

D. C. Pearce & J. W. Walker
Institute for Exploratory Research

U.S. Army Electronics Command
Fort Monmouth, New Jersey

The tunnel detection work at ECOM is the outgrowth of an in-house program entitled Electromagnetic Propagation in Solid Earth Media. Although originally addressed to communications problems such as antenna siting, this study is relevant to the electromagnetic detection of shallow tunnels. In fact the only significant difference between the problems is the relatively short range property of a shallow tunnel.

Our specific activity in the tunnel program was supported by MERDC under ENSURE #144. Our object was to develop a technique to predetermine the range in soils of EM detectors and to test the system at specific CONUS sites. This study is relevant to the problem of false alarms since the absence of a signal return could be interpreted as the absence of a tunnel rather than a consequence of a very dissipative soil.

The estimation technique employed, combines theory and empiricism and is an outgrowth of a systematic laboratory study. The significant component of the apparatus is a soil conductivity cell, especially designed to eliminate misleading spurious electrode effects. For timely accomplishment of the field studies the existing laboratory instrumentation was made mobile simply by incorporation in carryall vehicle. Although this resulted in a system much more sophisticated than necessary, the desired results were obtained quickly without difficulty. A series of measurements were made, by vertical drilling at three sites, EPG Fort Belvoir, N.C. State Central Crops Farm, Clayton, N. C., and S. W. Research Tunnel Site, San Antonio, Texas.

Concurrent with the above work, a laboratory study of the electrical properties of SEA soils is in progress. These samples were kindly furnished by WES and by personnel of an ECOM quick reaction team. In the very near future, we intend to publish a report tabulating the electrical properties of the SEA samples we have been able to obtain.

Figure 1 illustrates the attenuation properties of the samples that have been analyzed to date. The frequency range shown is considered appropriate to the tunnel detection problem. It is immediately obvious that in spite of the small number of samples, soil attenuation properties exhibit a substantial variation in magnitude. This certainly demonstrates the feasibility of an investigation of possible false alarms arising solely from soil conditions.

Discussion of these results within a geological framework is important. Although it is possible to crudely predict areas of high and low attenuation from considerations of region geology, soil or sediment origin and environmental development there is no apparent relationship between the electrical properties of soils and existing classifications based on civil engineering or agricultural considerations.

The grouping of the curves of Fig. 1 is not random but illustrates a classification in which soils and unconsolidated sediments can be placed. The low attenuation group (EPG, N.C., Cu Chi and Phuoc Vinh) are chiefly sands of quartz or rock fragment composition while the Midway formation of San Antonio is typical of alkaline soils and evaporites. The New Jersey sample which was selected because of its unique chemical properties, is also seen to be highly attenuating.

Although soils typified by the San Antonio and New Jersey specimens are unfavorable for EM detection methods they should not be unduly emphasized since these soil types and the conditions producing them have a very limited areal distribution. Furthermore, they are not considered to be of importance to the present tunnel detection problem. At the present time our knowledge of V.C. tunnel locations and regional soils indicate that the electrical properties of the medium should not preculde detection by EM devices. Finally the correct approach to the long range tunnel problem would appear to be to focus on known regions of tunnel activity or predictable tunnel activity and to consider the soil conditions of these areas only.

The extensive soil conductivity data already in existence can be utilized in this classification process. However it is important to note that most of this data is derived from wave tilt or electrical survey techniques. Strictly speaking a so-called "effective"conductivity is determined which is a complex average over a region of considerable areal extent and depth. Indiscriminate use of this effective conductivity data could well lead to erroneous conclusions for application to the detection of tunnels which are near-surface targets. On the other hand the ECOM technique is a point sampling process somewhat more appropriate to the tunnel problem. Presently it is our conjecture that utilization of geological considerations, selected point sampling and existing effective conductivity data should provide a wealth of information on soil properties particularly useful to the detection of shallow tunnels.

LOCATION and MOISTURE CONTENT

1. CU CHI 9.4%
2. E.P.G. FT. BELVOIR 13.0%
3. NORTH CAROLINA 21.2%
4. PHUOC VINH 10.0%
5. NEW JERSEY 11.0%
6. SAN ANTONIO 11.1%

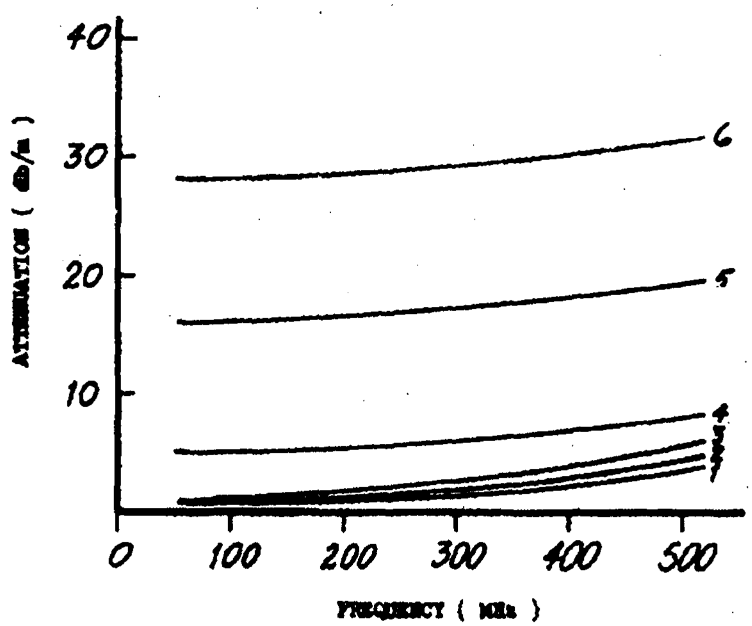


FIG 1

CONFERENCE OF INTERSERVICE COORDINATING GROUP

FOR TUNNEL PROGRAM - 29 OCTOBER 1968

Edgewood Arsenal Tunnel Denial Program

Mr. Joseph Sansonetti

A. Introduction

The project for tunnel denial at Edgewood Arsenal was essentially completed with the type classification of the new riot control agent CS2 and the M106 portable disperser. The agent was type classified on 9 April 1968 by AMCTC Action Number 6007 and the disperser was type classified on 16 December 1965 by AMCTC Action Number 3935.

B. Production

Agent CS2 is in production and approximately 468,000 pounds have been produced to date. This, however, is not used exclusively for tunnel denial. Other applications have been developed and are in use in Southeast Asia. Some of these uses are: vehicular denial, terrain denial, and search and destroy roles.

Twenty-two hundred M106 dispersers have been manufactured and issued, and there are ninety three more on order at the present time. This disperser has other roles beside tunnel denial. It is used in riot control, with the Picatinny Arsenal XM69 tunnel destruct system, and as a means for dispersing insecticides and defoliant agents.

C. Present Program

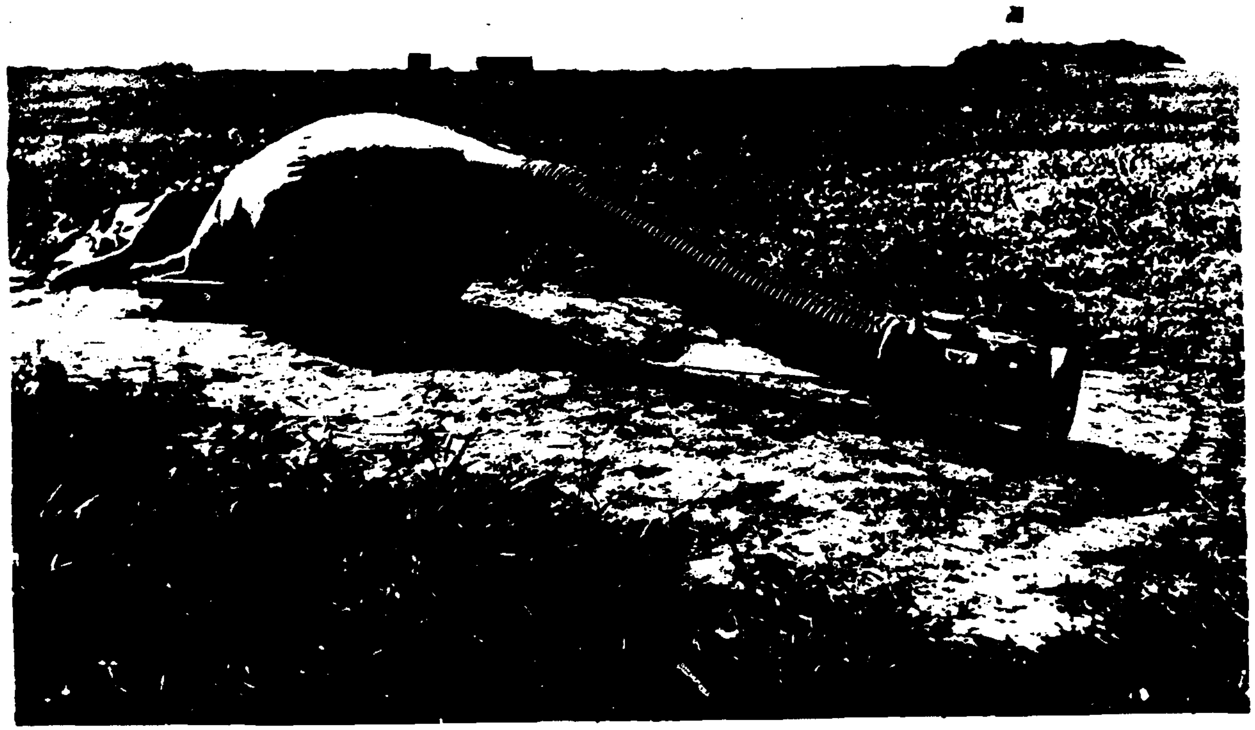
You may recall at the last briefing I discussed two chemical-mechanical systems that were under study. These were the use of natural or synthetic nettles incorporating irritant type agent and the use of low density foam incorporating riot control agents. Exploratory effort on these two approaches were completed. Because of the success of the simple CS2 agent blower system, engineering development of these more complex chemical-mechanical systems was not pursued further.

Recent requirements by the Military Police for the development of a limited barrier to control unruly crowds has regenerated interest in the use of the foam incorporating riot control agent. This program has been funded and initiated.

Because of the limited capability of the M106 blower to disperse agent throughout longer and deeper tunnel complexes, a requirement was established for a larger capacity blower. This was given ENSURE Number 34. In addition to the requirement for tunnel denial, it was requested that the blower be capable of providing fresh air in the tunnel to aid tunnel searchers.

The blower under development has been given the number XM26 and is seen in figure 1. This blower is basically a gasoline engine driven fan enclosed in an aluminum housing. The engine is light weight, air cooled, high speed, two stroke cycle, and is coupled directly to the axial flow fan. The unit is man portable, weighing 39 pounds and it generates 4500 cfm at 7 inches of water back pressure. In tunnel use, the blower is connected to the tunnel entrance by means of a flexible duct, the end of which includes a tunnel closure system as shown in figure 2. The closure is essentially an inflatable bag that seals the transfer duct to any configuration of tunnel opening.

Three prototype units were developed and tested. Performance of the units was very good; however, the units were not reliable. The unit has been redesigned to meet a minimum of 50 hours endurance and for increased reliability. Three units are on order. These units will be subjected to Suitability Insurance Testing as specified in ENSURE procedure. Testing is scheduled to be initiated the first part of December. On successfully passing these tests, a contract will be let for 26 units required for operational evaluation in Southeast Asia.



US Army Munitions Command - Picatinny Arsenal
Dover, New Jersey

Presentation on Tunnel Destruction

Mr. Martin Bachthaler
Mr. Bela Torok

BACKGROUND AND REQUIREMENTS.

Current Munitions Command efforts in the field of tunnel destruct are centered on the XM242 liquid explosive demolition kit now in SEA for field evaluation. For those of you who did not attend the previous meeting of this group, I would like to review some of the highlights of the program leading up to the current evaluation.

Work on the liquid explosive system was initiated at Picatinny Arsenal in April 1967 as a follow-on to the XM69 Demolition Set which utilized acetylene gas and received a lukewarm reception in SEA. Military requirements for the liquid system were established as follows: overburden up to 10 m, diameter up to 2 m, length up to 450 m; tunnel entry was not only permitted but required for purposes of exploration prior to destruction.

Breadboard feasibility was successfully demonstrated in July 1967 when an augured tunnel with overburden varying from 9 to 31 feet was destroyed by 6 lb/ft of PLX (for Picatinny Liquid Explosive, or nitromethane sensitized with 5% ethylene/diamine). Based on the demonstrated concept and subsequent engineering development work, the system was finalized using unsensitized nitromethane. Fabrication of evaluation hardware was completed in July 1968, and 30 systems were sent to SEA in August 1968.

EXISTING EQUIPMENT.

The Demolition Kit, Liquid Explosive: Tunnel Destruct, XM242 consists of 2 - 500 lb drums of nitromethane, a gasoline-powered air compressor, a drag pack containing 500 feet of nylon-neoprene lay-flat tubing with an explosion arrester loop, and assorted plumbing and accessories. The compressor, tubing, and accessories are packed in a third drum. All three drums are palletized and strapped to form a single package weighing 1320 lb, deliverable by helicopter or truck.

Briefly, operation of the system is as follows:

SLIDE

RESULTS OF FIELD EVALUATION.

The evaluation team, comprised of the PA project engineer, Mr. Bill Torok, and the contractor's representative, Mr. Marshall Klopich, arrived in Vietnam in August 1968 immediately following delivery of the hardware. Unfortunately, usable tunnels proved very difficult to locate, and it was necessary to send Mr. Torok back after six weeks without a single demonstration. Mr. Klopich remained in VN and a tunnel was eventually located. Following a series of minor mishaps and problems with twisted tubing in setting up the first test, it was finally decided to blow up that portion of the tubing which contained nitromethane and ignore the remainder. In describing the results, I'll quote portions of a 16 Oct letter from USARV to PA which discusses this test and makes specific recommendations.

The hardware now undergoing field evaluation is being used to demonstrate military potential. At this time, no efforts beyond that point have been scheduled. Future Munitions Command actions in the tunnel destruct category will be dictated by the USARV evaluation of this system and the funding picture at that time.

Mr. Torok is available to answer questions concerning both the hardware and its evaluation. Mr. Shepherd Levmore of PA will speak on "Safety in Handling and Storage of Liquid Explosives".

DEPARTMENT OF THE ARMY
HEADQUARTERS, UNITED STATES ARMY VIETNAM
APO SAN FRANCISCO 96375

IN REPLY REFER TO

AVHAT-GCD

16 OCT 1968

SUBJECT: Liquid Explosive Tunnel Destruction System (LETUDS)

Commanding Officer
Picatinny Arsenal
ATTN: SMUPA-D (Mr. B. Torok)
Dover, New Jersey 07801

1. On 6 Oct 68 the XM242 Tunnel Destruction Kit was used in an attempt to destroy approximately 650 feet of a Viet Cong tunnel. The tunnel was constructed in sandy clay. Overburden on the tunnel varied from 10 feet to approximately 3 feet. The tunnel was 18 to 24 inches wide and varied in height from 3 feet near the entrance to about 8 inches where soil had washed in close to the far end.

2. Two kits were set up with 4 barrels in line and the nearest barrel approximately 50 feet from the tunnel entrance. Beginning at the tunnel entrance, 2 men laid the 650 feet of tubing in approximately 50 minutes. Total time elapsed from arrival of kits to transfer of explosive was 2 hours.

3. When the compressor was turned on and transfer of explosive began, a number of twists were found in the section of tubing between the nitromethane drums and the tunnel entrance. These pushed down the tube until they were stopped at the explosion arrester loop block. It was necessary to cut the block out of the loop to remove the twists and then replace it on the line. A number of twists pushed on down the tube into the tunnel, causing the tube to roll from side to side. This caused the wires to the detonator, which had been placed about 100 feet down the tunnel, to tangle with the tube. The wires stopped the twists from pushing on down the tube and arrested the flow of liquid. At his firing position, a foxhole approximately 75 yards from the tunnel entrance, the operator saw the flow meter light go out in the electronic monitor box. He assumed that the flow had stopped because the tube in the tunnel was full and he fired the detonator. No nitromethane had reached the detonator, because the detonator wires tangled in the tube had stopped the flow about 25 feet from the tunnel entrance. Firing the detonator destroyed a section of the empty tubing.

Remedial action was taken. The wires were untangled and cut away from the tube and the destroyed section of tube was replaced. An attempt was made to remove the twists from the tube. All of the twists could not be removed and liquid explosive seeped on ahead of some of the twists. These twists then could not push freely down the tube even though the obstructing detonator wires had been removed. The operator worked the obstructing twists down the tube in the tunnel slightly more than 100 feet. Attempts to work the twists beyond this point were not successful. Working with the tube and wire caused leaks to develop in the tube. These leaks were patched with black electrical tape. Numerous pinholes also developed in the tubing. Considerable quantities of nitromethane had accumulated and pooled on the tunnel floor. The tunnel was full of heavy fumes from the explosion of the C4 detonator and from the accumulation of nitromethane. Because of the fumes, an oxygen breathing apparatus was required by the man working in the tunnel. This limited his working time to a maximum of 45 minutes in the tunnel. Additional tubing for a complete new line was not available at the tunnel site. Because of the late hour, the limited time an individual could remain in the tunnel, and the unavailability of additional tubing, it was decided to destroy the portion of the tunnel containing the nitromethane. This would provide the required data about the effectiveness of the system in a typical VC tunnel.

4. When the detonator was fired, the explosion arrester loop did not function and the detonation propagated into the barrels. The above-ground explosion destroyed the system (four barrels, one compressor, and associated manifolds and valves).

5. The detonation in the tunnel completely destroyed the section of tunnel that contained filled tubing. At the place where nitromethane had accumulated in a pool on the tunnel floor, the tunnel was completely blown out, leaving a crater 80 feet long, 30 feet wide, and 12 feet deep. It cannot be accurately determined how much nitromethane had accumulated on the tunnel floor, but it may have been as much as one barrel (500 pounds). In areas where only the normal amount of explosive was in the tube, the explosion caused the tunnel to collapse. The trace of the tunnel could be seen as a depression on the surface. It was concluded that one tube should be adequate for up to 10 feet of overburden as recommended.

6. Two possible causes for the failure of the explosion arrester loop to function properly were discussed: Accumulation of nitromethane on the ground around the system or saturation of the styrofoam block in the explosion arrester loop with nitromethane. No pools of explosive had accumulated, but the ground was damp in places. It was speculated that there may have been enough of an accumulation to allow a detonation to

propagate and bypass the explosion arrester loop. The loop, however, was placed on high ground near the tunnel entrance where no explosive had accumulated. A more likely cause may have been the styrofoam block. If the block had been soaked with nitromethane, it may have become a block of explosive instead of an inert spacer.

7. The following modifications to the XM242 kit are proposed.

a. The tubing system between the nitromethane barrels and the tunnel entrance, including the explosion arrester loop, should be replaced with tubing that will not twist. The tubing used in the manifold modules between the barrels would be suitable. This should be packed as a separate component from the drag pack assembly.

b. The styrofoam block in the explosion arrester loop should be replaced with a non-porous substance.

c. The lead wires for the electronic monitor box should be extended to a minimum of 200 meters and the couplings should be modified so that more than one lead wire reel can be used in series. Two hundred meters of detonator lead wire should also be included in each kit.

d. The operating instructions should be revised to include minimum safe distance figures for detonation of the system, based on the amount of explosive above ground should premature detonation occur and the explosion arrester loop fail. Figures should be provided for personnel in the open as well as for protected personnel.

8. It is requested that Picatinny Arsenal conduct such tests as are necessary to determine the feasibility of the proposed modifications and comment on the modifications.

9. Comments are requested on the possible causes for the failure of the explosion arrester loop to function, as well as data on the number of tests actually made of the explosion arrester loop system and the conditions under which the tests were conducted.

10. Data is requested on the explosive properties of the styrofoam block impregnated with nitromethane, i.e., how much nitromethane must be in the block before it will propagate a detonation.

AVHAT-GCD
SUBJECT: Liquid Explosive Tunnel Destruction System (LETUDS)

11. USARV has suspended use of LETUDS as unsafe. No further evaluation or testing will be attempted until answers are received to the above questions and LETUDS procedures and equipment can be modified to ensure safe operation. It is requested that data be provided to the headquarters expeditiously with partial replies being made as the information becomes available.

FOR THE COMMANDER:

J.S. TAYLOR, JR.
Major, AGC
Asst Adjutant General

Copies furnished:
USARV G3
USARV G4
USARV Engr
USARV SA
CG, 1st Log Cmd
CG, I FFV
CG, II FFV
CG, XXIV Corps
CG, 1st Inf Div
CG, 4th Inf Div
CG, 9th Inf Div
CG, 25th Inf Div
CG, Americal Div
CG, 1st Cav Div (AM)
CG, 101st Airborne Div (AM)
CG, 18th Engr BDE
CG, 20th Engr BDE
CG, 173d Airborne BDE
CG, 199th Lt Inf BDE
CO, 11th ACR
CO, 5th SFGA
CG, III MAF
CG, CMAC
CG, 3d BDE 82d ABN Div

Office of the Defence
Research and Development Attache
Australian Embassy
Washington, D.C.

Tunnel Requirements and Programs

E. G. Hayman

Classified Document

Filed in

Physical and Engineering Sciences Division

CONFIDENTIAL

US Army Combat Developments Command
Fort Holabird, Maryland

Consideration on Tunnel Doctrine

Major Arthur S. Torf

REGRADED UNCLASSIFIED WHEN SEPARATED FROM CLASSIFIED INCLOSURES

CONFIDENTIAL

CSGIN-M 28 October 1968

TITLE: Draft Proposed Qualitative Materiel Development Objective for a Tunnel Detection System (TDS) (U)

Section I - Statement of Objectives

1. (C) Statement of Objective.

a. Tunnel Detection System (TDS).

b. A device or system is required to detect anomalies beneath the earth's surface which may be indicators of tunnels, caves, and caches used by insurgents in operations against US Forces. The system must be capable of operation from aerial, ground-based, and man-packed surveillance platforms envisioned for the 1975-1985 time frame. It must be capable of 95 percent operational reliability and possess sufficient accuracy to permit preparation of 1:50,000 scale map overlays. It must be capable of detecting subterranean works of man with an earth cover of 10 feet. The equipment must provide for an acceptable degree of security from enemy countermeasures, and positive destruction devices should be designed into the system to prevent its use in case of capture.

c. The system must include a terminal either in the surveillance vehicle or on the ground where acquired information is presented to the operator in a form suitable for evaluation and interpretation. This representation must be of such form as to permit an accurate tunnel layout to be plotted.

d. The basic principle of surveillance as applied to this QMDO is to:

(1) Exploit significant changes in the local geography that differentiate these changes from the local natural environment.

(2) Exploit a characteristic emanation from the enemy environment that differentiates it from the local natural environment.

(3) Examine historical documents and aerial photographs for indications of change in the cultural composition of the area under study.

Section II - Operational Concepts

2. (C) Operational Concepts.

a. The Tunnel Detection System (TDS) will be employed within the combat zone to support intelligence and security operations at field army, corps, and division echelons.

CSCIN-M 28 October 1968

b. The operational concept of the TDS is highly dependent upon the nature of the equipment eventually developed. It is anticipated, however, that the TDS will initially consist in part of one or more sensors mounted on a 3/4 ton truck and later both man-packed and mounted on an aerial platform. The expected inertia and slow response of the system will probably preclude use from rapidly moving fixed-wing surveillance aircraft. Current research seems to suggest the following major approaches.

(1) Seismic/Acoustic sensors using sounding and/or listening techniques.

(2) Electromagnetic sensors using earth propagation techniques.

(3) Magnetic sensors for detecting ferrous materiels in tunnels.

(4) Gaseous effluent/condensation nuclei sensors for detecting exhaust port emissions.

(5) Conventional aerial photography to provide evidence of excavations.

(6) Infrared sensors.

c. The final TDS may consist of a multisensor system covering several aspects of the previous paragraph because:

(1) Greater effectiveness may be possible by correlation of multiple sensor outputs.

(2) The several levels of warfare include varying degrees of enemy air defense which could affect the operational concept and selection of sensors.

(3) The effectiveness of the sensor will vary with the composition of the soil in the area.

d. The TDS requirement may be satisfied by a system which emphasizes a rapid, unique technique of analysis and correlation of historical and current sensory data in an effort to detect changes in information content.

e. The considerations contained in the foregoing paragraphs support the possibility that at least three operational concepts will be employed.

(1) A large area, long range concept for recurring systematic coverage.

(2) A localized area, short range coverage to determine secure locations of base camps, airfields, etc.

(3) A continuous surveillance of a localized area to detect new mining or sapper operations by the enemy.

In all cases equipment will be used by combat troops and results provided to the echelon Battlefield Information and Control Center (BICC) for analysis and formation of a tunnel plot and intelligence report. Denial and destruction operations will be governed by the tactical situation and the decision of the maneuver unit commander.

f. The system and its operation concept must be compatible with the total reconnaissance and surveillance concept. In this respect, it can be anticipated that target data will be fed into the Tactical Operations System (TOS) for immediate correlation with other battlefield surveillance data.

3. ~~(C)~~ Organizational Concepts. The number of systems required at various echelons will be dependent upon their configuration (size, weight, and sophistication), and will have to be reviewed concurrently with the development of the detector. It is envisioned that ground-based versions of the system will be found at division level and below, down to and including the company. Aerial versions will, because of increased size and complexity, be located at corps echelons. Additional ground-based systems will be found at the Military Police and Engineer battalions responsible for or operating in security or rear area protection roles. Equipment will be provided through normal supply channels, and will have an estimated useful life of fifteen years. Operating personnel should be able to perform organizational maintenance after completion of formal training on the specific equipment contained in the system.

Section III - Justification and Priority

4. ~~(C)~~ Reason for the Objective. One of the critical problems which has developed in the war in Vietnam has been the ability of the Viet Cong to conduct military operations utilizing bases consisting of elaborate systems of tunnels. These tunnels are difficult or impossible to locate using existing detection systems. A tunnel detection system will provide information which will enhance the security of field army units against tunnel operations and resulting enemy attack. This objective is supported by the USACDC study, Intelligence-75 (INTEL-75) (U).

5. ~~(C)~~ Priority. Priority I is recommended. This capability was identified by INTEL-75 as a gap or shortfall in the reconnaissance and surveillance program. Since a current conflict is involved, the highest priority and maximum effort in satisfying the requirement are indicated. This priority is particularly appropriate if an interim effort is initiated since, from a practical standpoint, only an interim system, based on state-of-the-art approaches can be related to the Vietnam conflict.

Section IV - Other Considerations

6. ~~(C)~~ Background.

a. References:

CSGIN-M 28 October 1968

(1) Letter, CDCMR-O, HQ, USACDC, 31 May 68, subject: Tunnel Detection and Neutralization, with three inclosures.

(2) Letter, CSGM-F, 24 Jun 68, subject: Tunnel Detection and Neutralization.

b. Referenced letters task USACDCCSG and USACDCINTA to prepare a QMDO which will allow research effort to continue toward the development of systems, techniques, and materiel for airborne and man-pack detection of tunnels.

c. A very widely used geophysical technique in exploration for oil is the seismic reflection method. A mechanical source creates a shock wave on the surface of the earth. The seismic wave generated spreads in all directions through the earth. When the waves hit a geological boundary or discontinuity, part of the energy is reflected back to the surface where it is received by strings of geophones. The signals from these geophones are recorded on magnetic tape and are played back in either digital or analog modes to provide a graphic display which shows the discontinuities as wave cycles in alignment over a portion of the plot. A proposed immediate approach is the utilization of modified aerial or hand emplaced geophones currently under consideration for use in USACDC Project HIGH GEAR. The mechanical shock wave can be supplied by the use of explosives and results obtained directly from the sensors and collected at a central point.

d. Initial detection systems will probably be limited to ground based platforms, except in the case of organic effluent detectors which have already been developed and are capable of fielding in aircraft. The Australian Army Operational Research Group has published Memorandum M30, dated February 1968, subject: The Prediction of the Location of Insurgent Installations by MAJ E.S. Holt, ptsc, RAE. This paper provides a detection approach which, if automated by the use of automatic data processing equipment and flying spot scanner techniques, could provide a moderately rapid and accurate approach to the problem.

e. If, during the development phase, it appears to the developing agency that the characteristics listed herein require the incorporation of certain impractical features and/or unnecessarily expensive and complicated components or devices, costly manufacturing methods or processes, critical materials, or restrictive specifications which prove excessively expensive or serve as a detriment to the military value of the unit, such matters shall be brought to the attention of the Chief of Research and Development, Department of the Army, and Headquarters, US Army Combat Developments Command, for consideration before incorporation into the final design.

7. (U) This materiel requirement is identified as USACDC Action Control Number 14390 and supports the following:

CSGIN-M 28 October 1968

a. Army Concept Program	Army 85 (1975-1985)
b. Study, "INTEL-75;" USACDC Action Control Number	6490
c. Army Tasks	1. High Intensity Conflict 2. Mid Intensity Conflict 3. Low Intensity Conflict Type I 4. Low Intensity Conflict Type II 7. Complementing of Allied Land Power
d. Phase	Materiel
e. Function	Intelligence

THE ANTHROPOMAGNETOMETER

Dr. Z. V. Harvalik,
US Army Advanced Materiel Concepts Agency

I would like to describe a potential tunnel detection instrument. It consists of a mechanical indicator and a highly complex electronic system of networks, probably reacting to magnetic anomalies. The indicator that permits to detect a magnetic anomaly, perhaps in addition to other anomalies, is an L-shaped rod of a metallic or nonmetallic material of the dimensions of 6 inches and 24 inches in length, the shorter portion of which is held by hand. Two of these indicator rods are usually used, one in each hand. When you level the rods, kept about 8 inches apart, to a parallel alignment by an appropriate twist of your arms, the tip of the rods being inclined toward the ground at about 1 to 2 degrees, you may be able to pick up a signal while walking over an anomaly. This signal can be observed as a crossing of the rods. The maximum of the crossing seems to appear at the center of the anomaly. I would venture that by now you recognize that this instrument is a divining rod.

The functioning of a divining rod is unknown. However, experiments and measurements have been made under controlled conditions, indicating that dowsing is not a hoax. We do not know as yet what biophysical, physiological, and psychological phenomena are involved in the peculiar action of the human body to perhaps magnetic anomalies.

For many years, I devoted a part of my spare time to the problem of dowsing, and I designed experiments to pin down certain salient parameters. First of all, the so-called indicator, i.e., the L-shaped wire or rod, indicates only that your arms twist inwards or outwards. The indicator rods probably have nothing to do with the interaction of the anomaly with the human body; they just show that the arms twist. This is the reason why the material of the rod, its shape and length, do not influence the convergence or divergence of the rods when an anomaly is detected. Thus, the understanding of the mechanism that causes the twist of the arms is of importance to assess the divining rod as a tunnel detector.

An experiment I designed may shed some light upon the nature of the phenomenon of dowsing. Two copper rods, 1/4 inch in diameter, were inserted 18 inches into the ground, 28 feet apart, oriented exactly magnetic East-West. The soil was of relatively dense, slightly sandy clay. The copper electrodes were connected with a DC power supply, located about 100 feet from the electrodes, the lead wires perpendicular to the proposed path of the current flow in the ground. The voltage of the power supply could be varied from 0 to 500 volts DC, with commutation facility. The dowser walked, at normal walking speed, perpendicular to the proposed current flow in the ground, at a location of about 14 feet from each electrode. (Walking or running speed has apparently no influence on the signals obtained.) When current was not on, no signal was observed in the vicinity of the proposed current path. However, when current was switched on and gradually increased while the dowser was walking forth and back in the above-mentioned fashion, at current of approximately 20 mA (at approximately 75 volts), a distinct anomaly signal appeared. The signal became very strong when the current reached approximately 40 mA at 120 volts.

A signal was received only when the negative electrode was at the left side of the dowser. When it was at the right side of the dowser, no signal could be observed. When AC was used instead of DC, under similar current and voltage conditions, the dowser received signals while walking in either direction.

Signals were also received when the dowser was not walking, but standing above the ground where the maximum current flow could be expected (straight line between the two electrodes). When the current was gradually increased from 0 to 20 mA, a signal started to appear at approximately 15 mA, AC or DC. However, in case of the utilization of DC, the dowser had to have the negative electrode at his left side. If the dowser faced the negative or positive electrode, thus standing in the direction of the current flow, signals were observed. A number of persons were tested in this fashion for ability of dowsing. The most sensitive one ever observed was able to produce a signal at around 2 to 3 mA, while the other extreme so far observed showed an incipient signal at 80 mA. About 80 percent of individuals used for the experiments showed aptitudes of dowsing.

The above-described experiments could be interpreted as follows:

(1) Changes of magnetic field gradients interact with man; the interaction of which can be detected by a twist of the arms.

(2) The interaction is a function of the direction of the magnetic field, thus suggesting that nuclear magnetic resonance of the hydrogen atoms, so abundantly present in the human body, are probably not contributory to the phenomenon of dowsing.

These experiments also lend themselves to identify, perhaps, the degree of dowsing abilities of individuals. Examples have shown that these experiments can be used to train in dowsing and to observe the progress of the training of persons. Using this technique, an individual who showed a dowsing ability of "50 mA" after half an hour of testing was able to react to a current of "25 mA."

It seems that the most important factor in the training for dowsing lies in the ability of the individual to detach himself psychologically from the manipulation of the indicator rods and thus perhaps physiologically from influencing, subconsciously or consciously, this twisting the arms. He should forget that he is holding the indicator rods and should pay attention to anything else than to the activity of dowsing.

If one assumes that man is able to detect magnetic anomalies by utilizing dowsing techniques, one is utterly amazed by the sensitivity of the human body to such anomalies. Magnetometric measurements indicate that a dowser reacts to magnetic gradient changes of 100 to 500 millimicrogauss.

Magnetic anomalies of the above mentioned order of magnitude can be anticipated practically everywhere. These anomalies can be caused by local variations of paramagnetic or even ferromagnetic properties of the soil. They also can be caused by discontinuities due to buried bolders; by cavities such as caves, culverts, or tunnels; by buried trash and corpses; by very slow-flowing ground water, and even by root systems of trees larger than 4 inches in diameter at the base.

So far, there is no means yet discovered to distinguish between the sources of the anomalies, thus making tunnel detection by dowsing a somewhat difficult procedure.

It should be mentioned that the anomalies affecting the dowser do not have to be generated from the ground. They can be also above the ground, such as power and telephone lines (live or dead), and metal structures such as bridges, railings, and fences.

It should also be mentioned that dowsing was successfully attempted from a moving car; however, the speed of the car should not exceed 25 MPH because of the difficulty of holding the dowsing rods in the appropriately sensitive position. Furthermore, the signals become blurred at the anomalies because of the short temporal exposure of the dowser to the field gradient change due to the car speed.

It should be mentioned also that the dowsing was attempted successfully from an aircraft, flying approximately 5,000 feet above the ground.

It seemed to be possible to determine the depth of the source of the anomaly: If one measures the distance between the first appearance of the signal and the maximum intensity of the signal, this distance seems to be also the depth of the source of the anomaly.

The documentation of statements made in this presentation is being assembled and will be issued as a separate report. It should be noted that the help of Mr. C. N. Johnson, of the Research Branch of the Detection, Intrusion, and Sensor Laboratory, MERDC, Fort Belvoir, is very much appreciated. A large number of experiments were performed by this author and Mr. Johnson during the early part of 1968.

Dowsing should not be written off entirely as a means of tunnel detection. It should be explored as a potential aid to detecting tunnels, weapons and materiel caches, and other objects of military interest. Training of personnel as dowsers and the research that may lead to the understanding of the biophysical mechanism of dowsing should be undertaken. This author would gladly amplify recommendations related to dowsing problems.

22 April 1968
Col Hall

CHRONOLOGICAL HISTORY OF

U.S. ARMY ADVANCED MATERIEL CONCEPTS AGENCY (AMCA)

The inception of AMCA was a result of a memorandum in January 1966 from the Assistant Secretary of the Army (R&D) to the Chief of R&D, Department of the Army, whereby the Assistant Secretary stated, "Army needs to find a way to use technological capability in a more creative way in the new concept and system optimization role." On 9 May 1966, a meeting was held under the auspices of ASA (R&D) and attended by the Commanding General, AMC, the Commanding General, CDC, and others, which was held to present various views. This meeting and a subsequent exchange of letters resulted in the establishment of the "Committee of Four" to examine the need for improved AMC/CDC coordination during the concept formulation phase. The most pertinent document exchange between ASA (R&D) and CG, AMC, was the letter of 2 June 1966 from ASA (R&D) to CG, AMC, stating three general points which were as follows:

1. A major Army problem is to anticipate technological advancement and translate that advancement into systems concepts directed at better meeting the Army's broad mission requirements.

2. Essential that AMC and CDC have a continuous exchange of views directed toward the common objective of Army improvement.

3. AMC and CDC devise organizational and procedural means for improving the overall coordination between commands during the concept formulation phase of the development cycle.

Concurrent with the above meeting and the establishment of the "Committee of Four", but independently, a study of Army test and evaluation (SATE) was being made. Chief of Staff Memorandum (CSM) 66-418, 20 September 1966, announced decisions on SATE recommendations. The decisions included extending the original charter of the "Committee of Four" The "Committee of Four" was composed of: Dr. Payne (OSA), Colonel Emerson (OASA), Dr. Siu (AMC), and Mr. Hardison (CDC). The "Committee of Four" charter objectives as extended by CSM 66-418 were as follows:

1. Find a way to use various technological capabilities in a more creative way in the new concept and system optimization role.

2. Explore Hq DA/AMC/CDC interface and methods of operation and recommend organizational and procedural means to improve coordination, particularly during concept formulation phase.

3. Recommend a division of existing resources to enable CDC to get started discharging its equipment evaluation responsibilities and additional resources to provide CDC a full capability.

The "Committee of Four" presented its report to the Chief of Staff on 17 November 1966. Six improvement suggestions were presented. These improvement suggestions were as follows:

1. A management model of research/combat developments/materiel development process.

2. Improvement in CDC capability to participate in planning, conduct, and evaluation of equipment service test.

3. Establish CDC capability for systems analysis of specific materiel items.

4. Establish an ACSI capability for forecasting long-range intelligence.

5. Establish an AMC capability for forecasting long-range scientific and technical information on materiel options.

6. Establish a CDC capability for developing alternative conceptual designs of the land combat system.

In essence, the latter three recommendations recommended the establishment of the U.S. Army Intelligence Threats Analysis Group (ITAG), AMCA, and CDC's Institute of Land Combat (ILC).

CSM 67-51 (9 February 1967) approved the recommendations of the "Committee of Four" and assigned the following missions: For the ILC/AMCA/ITAG complex--Prepare recommended designs of total land combat system and guide development of selected major materiel concepts through concept formulation. For ITAG--Provides threat forecasts responsive to AMCA/ILC requirements. For AMCA--Provides descriptions of alternative systems and concepts of materiel with which future forces could be equipped. Conducts some design work and serves as a contact point for concepts originating in AMC elements and industry during the concept formulation phase, complementing the ILC conceptual (design) studies of the land combat system. For ILC--Develops conceptual designs of the land combat system and conducts related selected studies and analyses to guide the development of Army doctrine, materiel, and organization during the concept formulation phase.

Based upon the mission statement for AMCA; a visualization of where the organization would function within the overall Army Management Model; and the major functions of land combat (Intelligence; Mobility; Fire Power; Command, Control, and Communications; Service Support); a tentative organizational structure and functions were submitted in May 1967. Generalized functions in this submission were as follows:

1. To be the primary working interface with CDC and ACSI for future concepts.

2. Advise, assist, and participate with CDC and ACSI in the formulation and development of future Army concepts and operational capability objectives.

3. Synthesis of advanced materiel concepts (with CDC and ACSI).

4. Exploit science and technology (maximize for Army purposes).

5. Identify critical science and technology gaps and formulate courses of action to close them. (Provide AMC an improved RDT&D program base).

The initial plan was staffed within Hq, DA, and returned at the end of July 1967 with the following general comments: TDA validated. One administrative support element to provide services to both ILC and AMCA. The mission statement, to conform with CSM 67-51 and clarification of functional responsibilities between the proposed Concept Synthesis Division and Exploratory Evaluation Division within AMCA. AMCA civilian grade structure should generally be compatible with that submitted by the Institute of Land Combat.

GENERAL DISCUSSION

LTC Louis G. Klinker - Discussion Leader

OUTLINE

Subject: Objectives for Research and Development Programs for Countering Tunnel Warfare

I. Tunnel Denial

Short Range Objectives

Long Range Objectives

II. Tunnel Destruction

Short Range Objectives

Long Range Objectives

III. Tunnel Dection

Short Range Development Programs

Seismic

Radar

Canine

Long Range Research and Development Programs

Wider Survey, Remote Detectors

Improved Ground Detectors

Man-Portable, Vehicular