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Slurry explosive	Large-scale card gap	Minimum air gap
Impact sensitivity	Projectile impact	Equation of state
Friction sensitivity	Explosion temperature	Energy density ratio
Electrostatic sensitivity	DTA/TGA	Detonation velocity
Cap sensitivity	Reaction kinetics	Wedge test

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of safety and performance tests were conducted on the slurry explosive Teledet. This and additional data generated by other agencies have been compiled to characterize this slurry explosive as a potential candidate for military use. Comparisons were made relative to safety, performance and cost with other explosive materials. The most favorable features of Teledet are its good safety characteristics, good chemical and thermal stability (for a slurry explosive), easy emplacement, and the ability to propagate in small diameters.

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19. Key Words (Contd)

Minimum propagation thickness
Tiger code
Compatibility
Oxygen balance

20. Abstract (Contd)

The features that may detract are the metal acceleration capability which is about 75% that of TNT, the separation of ingredients in low-viscosity Teledet, the inherent limitations with any slurry explosive, and the higher cost, relative to other slurry explosives.

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INTRODUCTION

On 29 October 1975 a group of DoD representatives were invited to witness a mine-clearing demonstration conducted by Teledyne McCormick Selph in Hollister, California (ref. 1). A Teledyne McCormick Selph (TMc/S) developed slurry explosive designated Teledet was used in the demonstration. The results obtained indicated that Teledet exhibited sufficient potential to warrant its evaluation and assessment for consideration in military applications.

Subsequently Headquarters, US Army Armament Command (ARMCOM) (ref. 2), requested that Picatinny Arsenal (now US Army Armament Research and Development Command (ARRADCOM)) conduct safety and performance tests on Teledet necessary to meet DoD directives. These tests were required prior to evaluating Teledet in any military application. The request included that Teledet be assessed to determine the need for the material, a comparison (including economics, safety, and performance) with similar materials in service, and government/company agreements needed, based on DoD limitations, to characterize/manufacture the slurry explosive.

The minimum safety and performance characteristics are required on Teledet so that other government agencies may initiate application programs. This report fills that requirement. Full characterization will depend on the success of the application programs and the availability of funds.

This evaluation places no commitment on the US Government for any future use of Teledet.

Based on the information available, Teledet, a water-based slurry explosive, was specifically developed as a thin-layer propagating explosive to be used for fracturing mineral formations. Also it may have been known as Dynafrac during the early stages of development.

During the past few years Teledet has been examined by various agencies, either to determine its sensitivity and performance or as a potential candidate in a specific application. The examiners included the Bureau of Explosives, Pittsburgh Mining and Safety Research Center at the US Bureau of Mines, Lawrence Livermore Laboratory (LLL), Mobility Research and Development Command (MERADCOM) at Fort Belvoir, VA, and Picatinny Arsenal (ARRADCOM).

The safety and performance tests conducted were in accordance with Army Technical Bulletin TB-700-2 (ref. 3) and the "Tri-Service Qualification Manual" (ref. 4), which is based on NAVORD Report

OD-44811 (ref. 5). Although some tests were repeated to verify safety levels, all data generated by various agencies have been compiled for incorporation in this report. This was done to eliminate duplication of effort and to economize on the costs for any future considerations.

Composition of Teledet Slurry Explosive

The explosive slurry Teledet consists of an ultra-fine explosive solid suspended in an energetic, but non-self explosive, liquid matrix and contains no liquid explosive ingredient.

Prior to conducting any experiments to evaluate or determine the explosive characteristics of Teledet, Picatinny Arsenal concluded an agreement which protected the proprietary rights of the manufacturer and also the involvement of the Government. Previously a similar arrangement had been made with LLL in the rock fracture studies in coal seams.

As the negotiations were being finalized between the manufacturer and Picatinny Arsenal, a patent was issued for the thin-layer propagating slurry explosive (ref. 6).

A typical composition of Teledet is as follows:

Ingredient	% by weight
PETN*	38.0 $\pm$ .5
Ammonium nitrate**	27 $\pm$ .5
Diethyleneglycol	9 $\pm$ .5
Guar Gum	.5
Water	25 $\pm$ .5

*This is ultra-fine particle size, sensitive PETN.
**This is a 60% ammonium nitrate solution

The desired consistency of the Teledet slurry is obtained by varying the amount of cross-linking agent and/or the thickener.

Two compositions were made available for testing. The less viscous material, designated Teledet Lot 006, has approximately 0.05% titanium tetraisopropoxide, while the more viscous material, designated Teledet Lot 22676, has 0.15% of the cross-linking agent.

Since these two formulations represent the extremes of viscosities expected to be encountered in any application of Teledet, tests on

these compositions should bracket any formulation changes which may be required by the application under study.

The only difference between the typical compositions furnished ARRADCOM and the slurry explosive described in the patent (ref. 5) is the cross-linking agent. In the patent a "satisfactory" agent is titanium-antimonium lactate while in the ARRADCOM compositions the agent was titanium tetraisopropoxide.

The Teledet slurry explosive studied by the Bureau of Mines (ref. 7) and LLL (ref. 8) carried the designation of Standard Teledet which is the same as the high viscosity composition. Also studied by the Bureau of Mines was a Type II Teledet slurry explosive. In this composition a salt had been added as a coolant and/or flame inhibiter so that it would not ignite brush when used to produce fire breaks.

On an overall basis the consistency can be adjusted from about 500 centipoise to a solid gel. In tubes a viscosity of 30,000 centipoise can be used while for spreading on the ground a viscosity of 125,000 centipoise is required. The difference in formulation is only 0.1% to 0.3% with no change in explosive properties with respect to viscosity (ref. 1).

Teledet is thixotropic, can be poured, sprayed or pumped, and can be produced in any color desired. Teledet can also be foamed. Normally the slurry is milky in color and resembles Elmer's glue in appearance.

Properties of Teledet Slurry Explosive

The sensitivity, detonation and performance characteristics of Teledet, a thin-layer propagating slurry explosive, are based on measurements made by ARRADCOM, Bureau of Mines (ref. 7), and LLL (ref. 8). The Bureau of Mines tests were performed for the manufacturer while the LLL tests were part of a coal gasification program. Preliminary stability and safety data had been determined by LLL on Teledet (ref. 9) and the results indicated no unusual safety hazards.

Details of each test are described elsewhere (ref. 3-5, 10). Modifications or related tests will be described. Wherever possible comparisons on a relative basis will be made with other explosives. A DOT explosive classification of Class A, Type III was assigned to this material in 1972 by the Bureau of Explosives based upon a series of mandatory tests (ref. 11).

Impact Sensitivity

On impact testing results were obtained using several different testers. This study showed that, with the NOL impact tester using Type 12 tools, no reactions were observed for the high and low viscosity Teledet in 20 trials at a height of 82 cm with a drop weight of 2.5 kg. (This was the limit of the apparatus.)

LLL, using a similar impact tester, obtained no reactions in 5 trials at 177 cm with a 2.5 kg drop weight. Data on several other impact testers were obtained with the Type 12A and 12B tools (ref. 10). (Type 12A is with sandpaper and Type 12B is without.)

The Bureau of Mines impact test was modified to improve the form of the impulse (ref. 7) delivered to the test sample. The modification substitutes a 2 kg drop weight and a 2 kg intermediate weight instead of the 5 kg drop weight and the 0.73 kg intermediate weight (ref. 12). The cup and plunger method was used. For Standard Teledet and Type II Teledet no reaction was observed at maximum drop heights of 250 cm.

The Teledyne McCormick Selph (TMc/S) impact apparatus consists of a 2.15 kg (4.73 lb) hardened steel striker with a .95 cm (3/8 in.) diameter and a steel anvil of the same diameter. No detonations occurred at a drop height of 63.5 cm (24 in.).

With the Bureau of Explosives impact tester (ref. 10) Teledet did not exhibit any reactions at a drop height of 9.5 cm (3 3/4 in.) with a 3.64 kg (8 lb) weight.

The only reactions that were obtained with an impact tester occurred with the Picatinny Arsenal impact apparatus (ref. 10). In this test the sample is in a cup and confined, and then impacted with a 2 kg drop weight. An explosion is defined as any audible or visual evidence of decomposition such as a crack, flash, smoke, or charring. The 10% value was obtained for both the high and low viscosity Teledets. Table 1 indicates the relative ranking with other explosives.

Table 1. 10% Point using PA impact apparatus - 2 kg drop weight*

Explosive	Height for 10% impact result	
	cm	inches
Lead azide	7.62	3
PETN	15.24	6
RDX	20.30	8
Comp B	35.60	14
TNT	38.10	15
Teledet (low viscosity)	40.60	16
Explosive D (ammonium picrate)	43.20	17
Teledet (high viscosity)	50.80	20

*(ref. 13)

Cap Sensitivity

Both the high viscosity (Lot 22676) and the low viscosity (Lot 006) Teledet compositions were initiated by a No. 6 electric blasting cap. This confirmed the findings of the Bureau of Mines who found that the Standard and Type II Teledets were sensitive to both No. 6 and No. 8 blasting caps.

Large-Scale Card Gap Sensitivity

The large-scale gap test (Explosive Shock Sensitiveness Test) (ref. 10) as developed by the Naval Ordnance Laboratory was used to determine the shock sensitivity of Teledet.

The results indicate that the 50% initiation point for the low-viscosity (Lot 006) Teledet was 211 1/2 cards or 5.37 cm (each card is 0.010 in.).

For the high viscosity (Lot 22676) the 50% point was 204 1/2 cards (2.045 in. or 5.20 cm). Table 2 compares the results with other secondaries. A No. 6 blasting cap was used for initiation. The results indicate that the shock sensitivity of both types of Teledet falls between Comp B and TNT according to the NOL large-scale gap test.

Table 2. Typical NOL large-scale gap test results including Teledet

Explosive	Density g/cm	50% point inches	50% point cm
RDX	1.64	3.23	8.20
Tetryl	1.62	2.61	6.63
Comp B (pressed)	1.66	2.38	6.05
Teledet (Lot 006)	1.39	2.12	5.34
Comp B (cast)	1.70	2.06	5.24
Teledet (Lot 22676)	1.40	2.05	5.21
TNT	1.60	1.83	4.65
Explosive D (ammonium picrate)	1.59	1.50	3.81

The Bureau of Mines conducted (ref. 7) a similar type test (ref. 12) with the exception that .635 cm (.25 in.) gap increments were used instead of .254 cm (.01 in.) cards. This test differs from the NOL test in that the loaded pipes have a smaller diameter and a longer length. Also No. 8 electric blasting cap is used instead of a No. 6.

Standard Teledet detonated with a 3.175 cm (1.25 in.) gap but failed with a 3.810 cm (1.5 in.) gap. Type II Teledet detonated with a 2.54 cm (1.0 in.) gap but failed with a 3.175 cm (1.25 in.) gap. The statement was made that neither material indicated any evidence of undergoing low-velocity detonation.

A comparison with other materials tested at the Bureau of Mines indicated that Standard Teledet exhibited the same shock sensitivity as Comp B and Commercial ANFO (X-1250) (ref. 14). With this test TNT also is less sensitive than Teledet.

Friction Sensitivity

The Bureau of Mines friction pendulum (ref. 4, 10) at Picatinny Arsenal (ARRADCOM) was used to determine if either the high or low viscosity Teledet explosive was sensitive to friction. Both materials were subjected to ten trials with the steel shoe and no reactions occurred. If a reaction had occurred then a fiber shoe would have been used.

For comparison purposes Comp B, TNT and Explosive D (ammonium picrate) passed the test with the steel shoe. However tetryl, RDX and PETN did not pass the test with the steel shoe but did pass with the fiber shoe.

The Bureau of Mines subjected the Standard and Type II Teledet explosives to the Julius Peters (BAM)[1] friction test. This friction apparatus (ref. 15) which is used extensively in Europe, originates in a mortar-and-pestle test. It consists of a porcelain plate upon which a sample (~ 50 mg) is located, and a pestle under load rests on the sample. One type has loads applied in the range 10-1000 g for primary explosives, and another type has loads applied from .5-36 kg for secondary explosives. By means of an electric mortar the porcelain plate is rotated back and forth in small arcs, the maximum velocity of the pestle relative to the plate being about 7 cm/sec.

Three grades of surface roughness are used, each pestle is used only once, and 6-10 tests are conducted for each load weight. Sensitivity is defined in terms of no reactions, partial reactions, inflammations, crackles and explosions.

The relative sensitivities of explosives are ranked in terms of a threshold initiation limit (TIL), which is the maximum load resulting in no reactions in 10 consecutive trials. In tests with both Standard and Type II Teledet no reactions occurred at the maximum load of 36 kg. For comparison purposes lead azide detonated in 4 of 6 trials with a 10 g load. The Bureau of Mines indicates that the BAM friction test with the 36 kg load appears to be a more severe test than the Bureau of Mines friction pendulum test with the steel shoe.

Electrostatic Sensitivity

In accordance with the interim qualification mandatory requirements (ref. 4,5) both the high and low viscosity Teledet were subjected to the electrostatic sensitivity test. With a voltage of 5000 V and a capacitance of .02 μfd (microfarad) each material was tested 20 consecutive times and no fires occurred at the 0.25 joule level.

A more stringent test was conducted by the Bureau of Mines (ref. 12). A maximum energy of 12.5 joules was obtained at which no reactions occurred for the Standard and Type II Teledet. In this test, if the maximum voltage was 5000 volts, the capacitance would be 1 μfd (microfarad).

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[1]The apparatus was developed and built according to the directions of the Bundesanstalt für Material prüfung (BAM) (German Federal Institute for Materials Testing).

Further testing was conducted at ARRADCOM. Both the high and low viscosity Teledet did not show any reactions at 2500 V with a 2 μfd capacitance. However with a 4 μfd capacitance both samples showed a reaction at a mimimum voltage of 1000 V. It should be noted that the average capacitance of a human being is in the pico-farad range.

Projectile Impact

The Bureau of Mines projectile impact test (ref. 10,12) was conducted on Standard and Type II Teledet. Each material was contained in 3.81 cm (1.5 in.) diameter by 7.62 cm (3 in.) long steel pipe nipple having a nominal wall thickness of .368 cm (0.145 in.). Both materials produced 50% initiation velocities (V_{50}) of approximately 900 m/sec. The projectiles are 1.27 cm (.5 in.) by 1.27 cm (.5 in.) brass cylinders faced square on the impact end and fired from a .50 caliber smooth-bore gun.

On a comparison basis in the same type of containment TNT produced a V_{50} of 1,271 m/sec, Comp B approximately 787 m/sec, and pentolite approximately 437 m/sec.

At the demonstration conducted by TMc/S on 29 October 1975 a .30 caliber bullet was fired into a plastic holder containing Teledet from a distance of 2.55 m (8 ft) with no reaction. The muzzle velocity in a .30 caliber is about 823 m/sec (2700 fps) (ref. 1).

TMc/S claims that Teledet samples, .159 cm (1/16 in.) thick, with aluminum and steel backings were not detonated by British caliber .303 with a muzzle velocity of 784 m/sec (2540 fps) or M-16 ball ammunition with a muzzle velocity of 1006 m/sec (3300 fps) at ranges of 22.86 to 30.48 m (75 to 100 ft).

Burn Test

A 5.08 cm (2 in.) cube sample of each type of Teledet (high and low viscosity) were placed on a bed of kerosene-soaked sawdust and ignited with an electric match. Neither sample exploded and the average burning time of the material was approximately 15 minutes (ref. 3).

In the demonstration at TMc/S Teledet was placed on a 30.48 cm (12 in.) long by 2.54 cm (1 in.) diameter plastic (PVC) pipe and burned with fuel oil. No detonation occurred (ref. 1).

In another test conducted by TMc/S, a vinyl tubing (.79 cm I.D. x 1.11 cm O.D. x 30.58 cm long) (5/16 in. x 7/16 in. x 10 ft 4 in. long) containing 2126 g/m (315 gr/ft) of Teledet was coiled on a plastic spool and placed in a wood fire. In eight minutes the vinyl tubing melted and the Teledet slowly burned away without any acceleration in the fire.

On a larger scale Teledet confined in a cardboard drum was burned with no evidence of flame-induced detonation (ref. 1).

Thermal Properties and Reaction Kinetics

The thermal properties and reaction kinetics of Teledet 006 and 22676 were studied by simultaneous DTA/TGA and DSC techniques.

Reaction kinetics by DSC

The Kissinger method was used to study the reaction kinetics of Teledet 006 and 22676. In this method, the variation in peak temperature with heating rate is used to determine the activation energy and frequency factor of the reaction. Samples weighing 2 to 4 mg were heated in a Perkin-Elmer Model DSC-1B differential scanning calorimeter at heating rates of 10, 20 and 40°C/min. from ambient to about 250°C in a dynamic helium atmosphere. Peak temperature (ΔT) was determined for each heating rate (ϕ) and values of $\ln\phi/\Delta T^2$ were plotted against $1/\Delta T$ in accordance with the equation

$$\frac{d\ (\ln\phi/\Delta T^2)}{d\ (1/\Delta T)} = -\frac{E}{R}$$

in which R is the gas constant. The slope of the line is used to calculate the activation energy (E) as shown in figure 1.

Frequency factors (A) were then determined from the equation

$$\ln\ (E\phi/RT^2) = \ln A - E/RT$$

Activation energy
Kissinger method

$$\text{Slope} = \frac{E}{2.303\ R}$$

Symbol	Teledet	Activation energy K cal/mole	Frequency factor $(sec)^{-1}$
O	006	32.7	1.04×10^{13}
Δ	22676	34.0	4.16×10^{13}

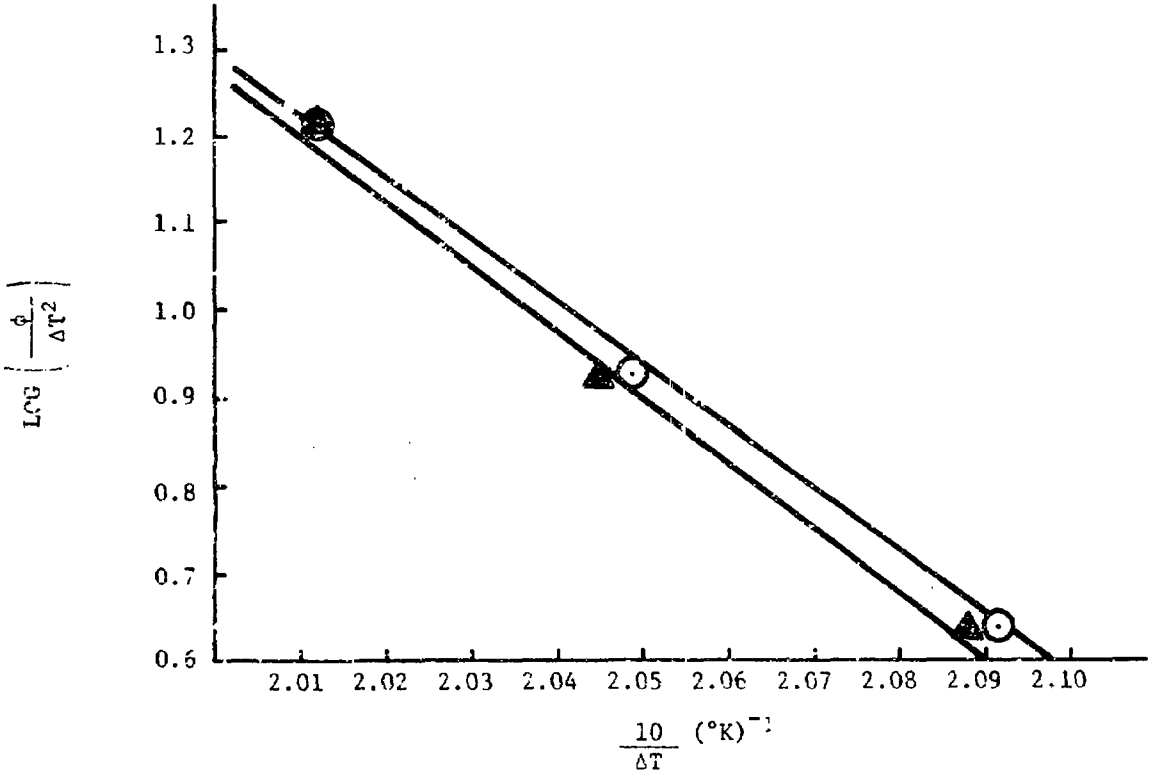


Figure 1. Activation energy of Teledet by Kissinger method

The following results were obtained:

Teledet	Activation energy kcal/mole	Frequency factor $(sec)^{-1}$
006	32.7	1.04×10^{13}
22676	34.0	4.16×10^{13}

The differences in the results are considered to be within experimental error. Calculations of specific reaction rate constants at 215°C were found to be 2.41×10^{-2} sec^{-1} and 2.45×10^{-2} sec^{-1} for Teledet 006 and 22676, respectively, showing the similarity in the reaction kinetics.

Low temperature thermal properties by DSC

Each sample was cycled in the DSC at 10°C/min from -100°C to 27°C and from 27°C to -100°C. During the heat up cycle of Teledet 22676, an endothermal peak for diethylene glycol/water mixture fusion occurred at -16°C. During the cool down cycle an exothermal peak was observed at -15°C (AN IV → V phase transition) followed by a second exotherm at -29°C (freezing of super cooled water).

As with Teledet 22676, Teledet 006 exhibited an endothermal fusion peak for ice at -16°C. However, during the cool down cycle two endothermal peaks occurred: one at -21°C and the other at -23°C which are attributed to impurities in AN during the IV → V phase change. These peaks were followed by another exotherm at -33°C resulting from freezing of the sample water with diethylene glycol.

High temperature thermal properties by DTA/TGA

The Mettler Thermoanalyzer - 2 was used to obtain simultaneous thermal traces of DTA, TGA and derivative TGA as a function of temperature. The Teledet samples (7 to 9 mg each) were heated in a static air atmosphere and in a flow of helium gas at 2° C/min from ambient through the decomposition temperature to determine their thermal characteristics at elevated temperatures.

The thermal behavior of Teledet in air was similar to that in helium. Both samples underwent weight loss in three s ges. The first stage involved weight loss up to 26% and was accompanied

by a broad endotherm over the temperature range ambient to 100°C attributed to the vaporization of water. This was followed by a 5% weight loss from 100°C to 145°C. During this intermediate stage, two endotherms were observed: one at 130°C and the other at 145°C resulting from the AN II → I phase change and the melting of PETN, respectively. The onset of the third stage of weight loss was at 145°C and was complete at 200°C during which the sample lost 65% of its original weight as a result of the decomposition of PETN (150°C) and AN (170°C) and their thermal reactions.

Explosion Temperature

The explosion temperature test is used as a means of determining the thermal sensitivity of an explosive material. By this method the time-to-explosion for a given temperature is determined. The relationship between the time-to-explosion and the temperature is expressed by the expression:

$$t = Ae^{E_a/RT}$$

where t is the time in seconds, E_a the activation energy in kcal/mole, A a constant dependent on geometry of experiment and composition of the material, T the explosion temperature in K, and R the universal gas constant. E_a is only an apparent activation energy since the entire explosive is not subjected simultaneously to isothermal heating.

The confined or closed method of obtaining the explosion temperature curves was first proposed by Henken and McGill (ref. 16) and modified by Zinn and Rogers (ref. 17) and others (ref. 18, 19).

A computer program at ARRADCOM has been developed in which the apparent activation energy is determined along with values for the time-to-explosion temperature. Based on the data input a correlation coefficient and a probability constant factor are also obtained.

The data obtained is listed in Table 3. It should be noted that this is a water-based slurry and that the time-to-explosion temperature is when the confined material ruptures the cap containing the explosive. For comparison purposes the 5-second time-to-explosion temperature for PETN is 228°C with an apparent activation energy of 18.12 kcal/mole (ref. 20). The 5-second temperature for ammonium nitrate is 465°C (ref. 13).

Table 3. Explosion temperature data

	Teledet Lot 006 (low viscosity)	Teledet Lot 22676 (high viscosity)
Apparent activation energy	26.94 kcal/mole	22.03 kcal/mole
Correlation coefficient	0.962	0.9511
Probability constant factor	1.187×15^9	1.07×10^{11}
Time-to-explosion		
1 sec	266°C	264°C
5 sec	227°C	231°C
10 sec	212°C	219°C

IR Spectra

An IR spectra was obtained on a sample of Teledet Lot 22676 which had been dried. The IR spectra is shown in figure 2. A review of the spectra indicates the following.

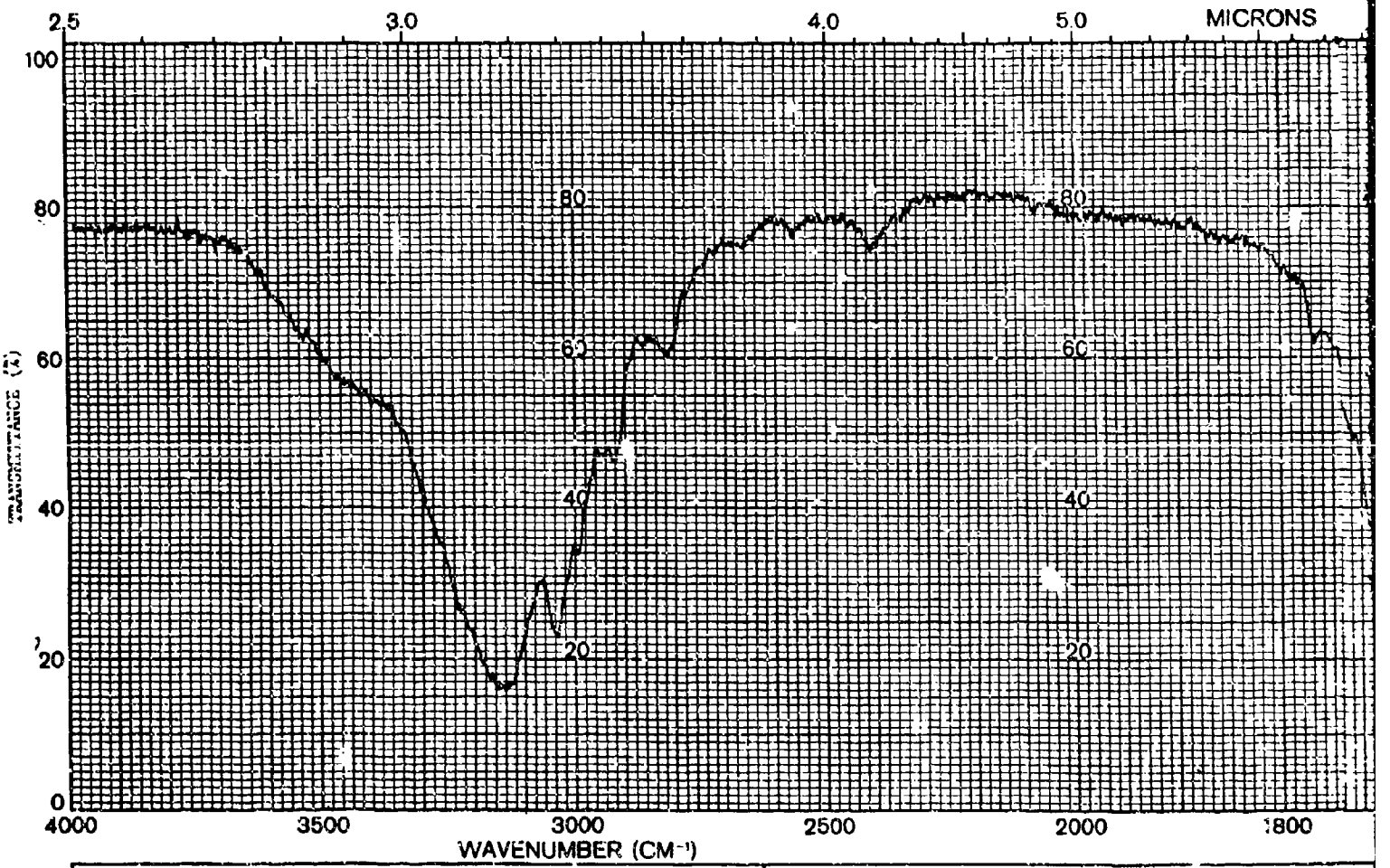
A very strong NH_4^+ ion signal appears at 3140 cm^{-1} and at 1390 cm^{-1}. There appears to be a strong NO_3^- signal at 860 cm^{-1} with an overlap signal in the 1340 to 1410 cm^{-1} range. There is CH_2 or alkane conformation at 2820 and 2920 cm^{-1}. The $-ONO_2$ activity is indicated at 1650 and 1290 cm^{-1}. There is a possible -OH indication at 3600 to 3500 cm^{-1} but it fades into the NH region which prevents a clear-cut identity.

On comparing the Teledet spectra with pure spectra of ammonium nitrate, PETN and diethylene glycol the following was observed:

1. The location of peaks at 3140, 1390, and 860 cm^{-1} indicates that ammonium nitrate is present.

2. The presence of PETN is shown by the overlap from 1200 to 600 cm^{-1}, 1275 to 1290 cm^{-1}, 1010 to 1042 cm^{-1}, 945, 855, 760, and 755 cm^{-1} regions.

3. The presence of diethylene glycol could not be confirmed since the sample had been dried.



SAMPLE Tcledet	SOLVENT
ORIGIN Dried (residue)	CONCENTRATION CELL PATH REFERENCE

Figure 2. I

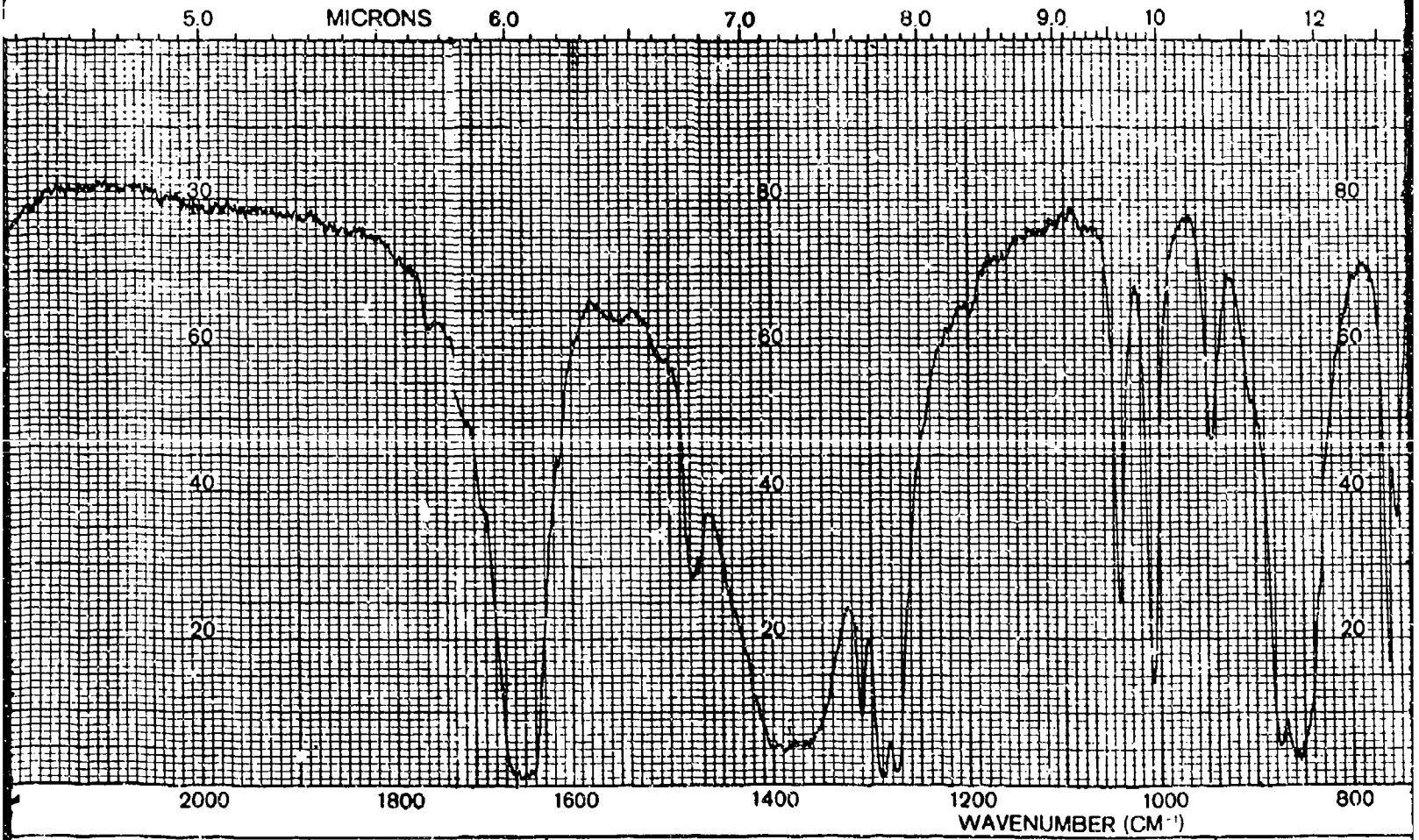


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Figure 2. IR Spectra of Teledet (Lot 22676)(dried).

SCAN SPEED _____
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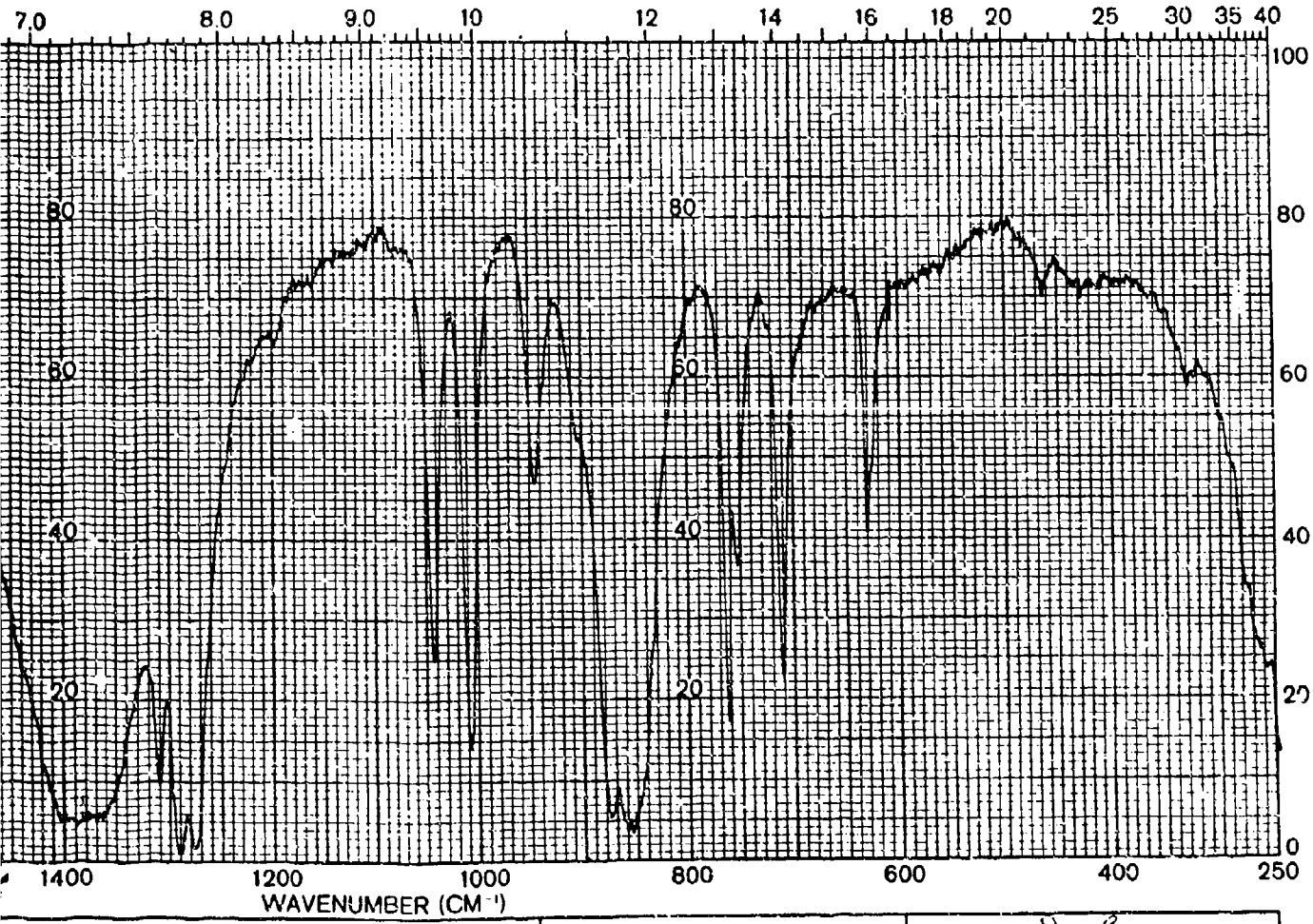

Lot 22676)(dried).

SCAN SPEED
SLIT
OPERATOR J.L.
DATE Apr. 29, 1977

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BUFFALO NEW YORK
PART NO. 457-5001

REF. No.

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For a positive identificatior of the Teledet spectra a composite or synthetic mixture of the ingredients in the proper ratio must be made and then the two spectra can be compared.

Compatibility

In the coal gasification program at LLL the compatibility of Teledet and other candidate explosives was tested in mixtures containing 50% explosive, 25% crushed coal and 25% water (ref. 21). The test conditions were 6.9 MPa (1000 psig) and 50°C with the compatibility equipment shown in figure 3. The purpose was to simulate conditions to be encountered in coal fracture work. Impact sensitivity and differential thermal analysis (DTA) tests were run on Teledet before testing and on the mixture after one- and two-week exposures to the test conditions. No reactions were observed on the drop hammer test, and only trivial changes were noticed on the DTA thermograms.

Since Teledet had been developed originally as a thin-layer propagating explosive to be used for fracturing mineral formations, the components of that explosive were selected to avoid incompatibility with contaminants found in the downhole environment. As indicated by the composition it does not contain any alkyl nitro compounds, amines, or hydrazine derivatives. As a means of verifying the compatibility of Teledet with contaminants found in or around oil and gas wells as well as mineral deposits, Teledet was mixed with equal volumes of 5 to 50% concentration acetic and nitric acids, sodium hydroxide, sodium carbonate, calcium chloride, and various crude oils with varying amounts of sulfur. These mixtures were subjected to 70 MPa (703 kg/cm^2) (10,000 psi) for 18-22 hours at a temperature of 82-88°C. The mixtures were detonated while under pressure in the temperature environment without any loss in explosive power (ref. 1).

The compatibility of Teledet with metals has not been fully investigated. It is known that ammonium nitrate in the presence of moisture reacts with copper, iron, steel, brass, lead, and cadmium (ref. 12). Also copper, brass, magnesium and mild steel are some of the metals affected in the presence of wet PETN. The specific application of the Teledet explosive will dictate further studies with various materials relative to packaging and/or end-item configuration.

Adiabatic Dynamic Compression

To simulate another downhole environment a test was devised to subject the Teledet explosive to an adiabatic dynamic compression. A 20-gram sample of Teledet was loaded into a cl ed-end steel cylinder

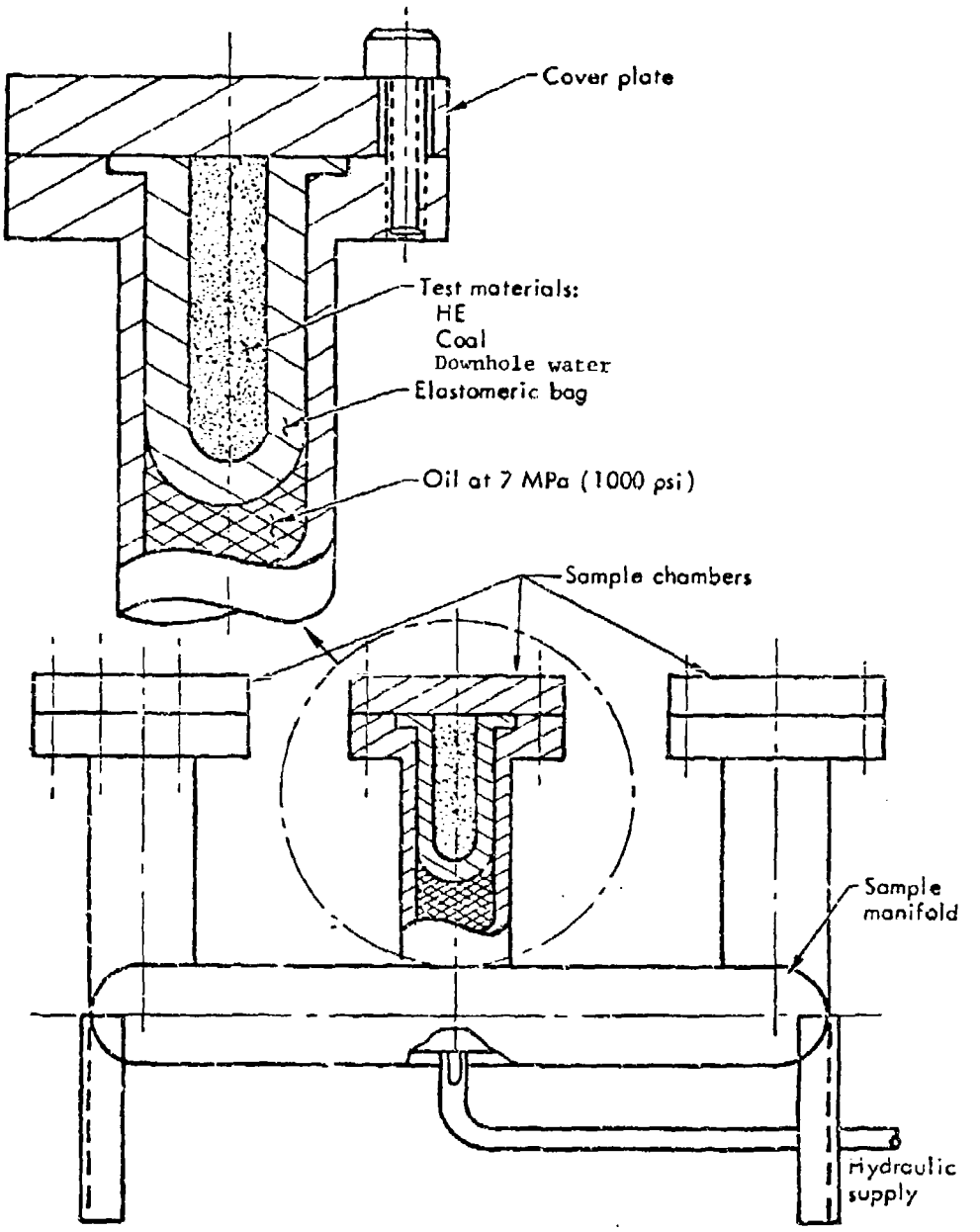


Figure 3. Compatibility equipment for use in testing a combination of explosive, coal, and downhole water (ref. 13).

with an inside diameter of 2.67 cm. Four grams of water were added and a steel piston was seated in the bore of the cylinder. In the remaining free volume of the cylinder five grams of propellant were loaded and the unit was sealed with a high pressure closure containing an electric squib. The propellant was initiated, developing a pressure of 140 MPa (1406 kg/cm^2) (20,000 psi) in about five milliseconds (ref. 1). Visual inspection of the slurry after removal from the cylinder did not reveal any changes, and the sample was detonated high order with a blasting cap without any apparent decrease in explosive power (ref. 22). This test was repeated twice with the same effects.

Detonation Properties - Experimental and Analytical

Detonation velocity

Detonation velocity tests were conducted on the high and low viscosity Teledet explosives using the apparatus shown in figure 4 (ref. 4). The explosives were loaded into aluminum tubing .635 cm ID, .080 cm wall thickness and 15.24 cm in length. Two tests were conducted on each sample.

The high viscosity Teledet (Lot 22676) produced an average detonation velocity of 6.503 mm/μsec based on readings of 6.332 and 6.673 mm/μsec (km/sec) for the two tests with a density of 1.40 g/cc. Using the relationship $P = \rho D^2/4$, the calculated detonation pressure is 14.8 GPa (148 kbar).

The low viscosity Teledet (Lot 006) produced an average detonation velocity of 6.225 mm/μsec for the tests with a density of 1.39 g/cc. With these values the detonation pressure is calculated to be 13.5 GPa (135 kbar).

In the Bureau of Mines study (ref. 7) a detonation rate of 6.74 mm/μsec was obtained for Standard Teledet (same as the high viscosity material) using 2.54 cm inside diameter steel tubes having a wall thickness of 0.32 cm boostered with a 4.13 cm diameter by 2.54 cm long tetryl pellet. For Type II Teledet a value of 5.65 mm/μsec was determined.

In the LLL program (ref 8, 23, 24) a detonation velocity measurement was included in the cylinder wall expansion test (to be discussed). With the 6.4 mm and 25 mm copper cylinders detonation velocities of 6.49 and 6.52 mm/μsec, respectively, were measured.

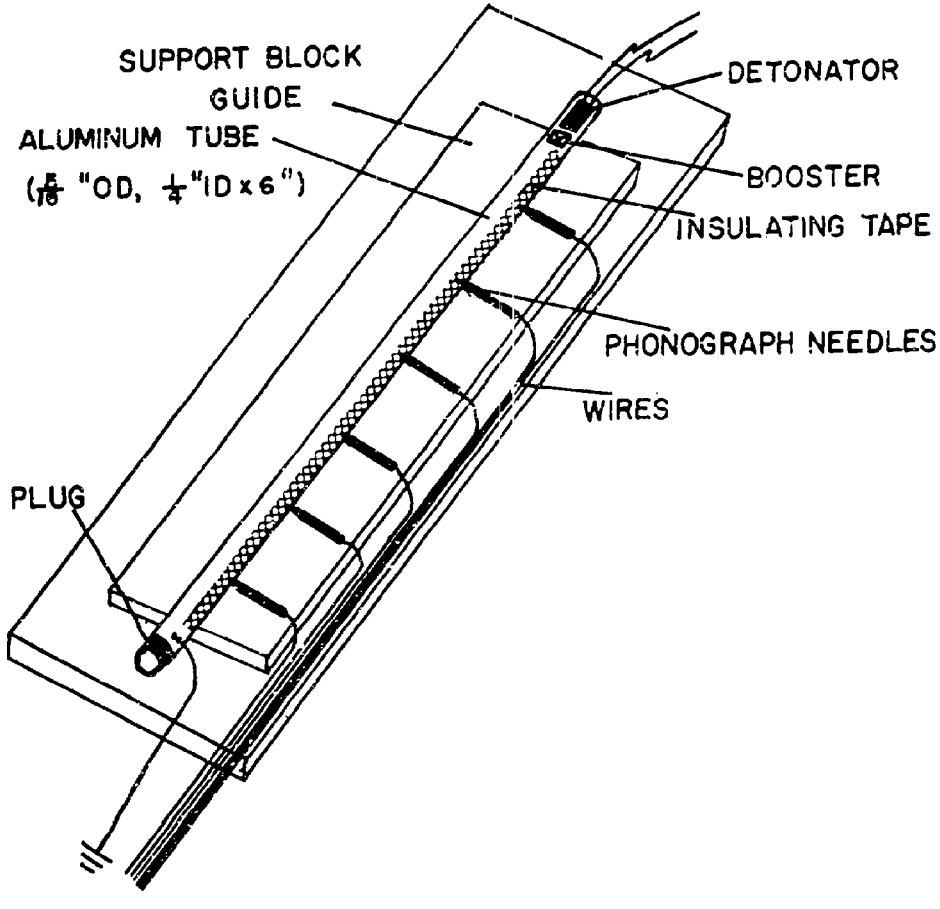


Figure 4. Detonation velocity apparatus.

Wedge test - minimum propagation thickness

The wedge test (ref. 12) which was conducted by the Bureau of Mines (ref. 7) is a method to evaluate the shock sensitivity of an explosive by studying the extent to which a detonation propagates in a thin film of the sample material. Simply, a wedge of explosive is initiated and the film thickness is determined for which propagation ceases. In this test the explosive wedge was 10.16 cm (4 in.) wide and 45.72 cm (18 in.) long and varied in thickness from 1.27 cm (0.5 in.) at the boostered end to essentially zero at the downstream end. The charge container was constructed of lucite and had a 1.27 cm thick base and an open top. The Standard Teledet produced a minimum film thickness for propagation of 0.036 cm (.014 in.) and a detonation rate of 6.74 mm/μsec; the corresponding values for Teledet II were 0.223 cm (0.088 in.) and 5.65 mm/μsec. The detonation rates verified the values obtained in the 2.54 cm diameter steel tubes. In the wedge test neither material displayed any tendency to transit from high- to low-velocity detonation as the layer thickness decreased.

In addition the manufacturer of Teledet reports (ref. 22) that the minimum thin-layer propagation thickness of that material has been measured in tapered wedge assemblies at atmospheric pressure, elevated pressure, and elevated temperature and pressure.

At atmospheric pressure a sample of Teledet completely detonated when confined between aluminum plates forming a wedge 25.4 cm in length and tapering from .635 to .040 cm (1/4 to 1/64 inch).

Complete detonation occurred when a sample of Teledet confined between masonite strips with a .16 cm separation was initiated with a No. 8 blasting cap. The assembly was subjected to 70 MPa (10,000 psi) in a pressure bomb for three hours prior to initiation.

For the elevated temperature and pressure environment a sample of Teledet was confined between 43.18 cm long by 8.15 cm wide aluminum plates, tapering from .254 cm to .076 cm. While under 70 MPa (10,000 psi) at 88°C the sample was exposed for 24 hours to a mixture of one part high sulfur crude oil, one part hydraulic oil and two parts water. The sample was initiated by a high-pressure blasting cap firing into a RDX booster pellet imbedded in Detasheet C. The evidence available indicated that the crude oil/hydraulic oil/water mixture displaced some of the Teledet near the end of the wedge suggesting that the minimum propagating thickness was less than the observed 0.091 cm (0.036 in.).

It is interesting to note that for PETN with particle size of 0.05 - 0.1 mm and a density of 1.0 g/cm the critical diameter is 1.0 mm, while for AN (ammonium nitrate) with a particle size of 0.05 - 0.2 mm and a density of 0.9 - 1.0 g/cc the critical diameter is 100 mm (ref. 24).

Cylinder wall expansion test - equation-of-state

The most versatile test for determining the relative performance of an explosive is the cylinder wall expansion test (ref. 4, 25). This is an accurate hydrodynamic test to measure the relative metal accelerating ability of the explosive.

To evaluate Teledet's performance in the coal gasification program (ref. 23, 26), LLL determined its P, V, E isentrope and detonation velocity in 6.35 and 25.4 mm copper cylinders with the cylinder expansion test. The behavior of Teledet in isentropic expansion and detonation velocity is very similar to "ideal" or "high" explosives. For an ideal explosive upon detonation the chemical reactions occur in a time scale that is short compared to the times required for the gases generated in the explosive to flow and the stress waves to propagate into the surrounding media.

From this data an equation-of-state was calculated for Teledet. The equation-of-state was constrained to match the 6.35 and 25.4 mm cylinder tests and also a thermochemical (TIGER) calculation of the energy based on the chemical data supplied by the manufacturer. The C-J parameters and the JWL (Jones-Wilkens-Lee) coefficients are given in table 4. The relative isentrope energies of Teledet and several non-aluminized blasting agents which were determined from the cylinder tests and compared to nitromethane (NM) are shown in figure 5. A plot of the Teledet expansion adiabat is shown in figure 6 (ref. 27).

Although the comparison was made with nitromethane the experimental isentropic energy values for NM and TNT indicate that the metal acceleration ability of NM is approximately 75% of TNT (ref. 28). In order to compare Teledet with other high explosives the index proposed by Alster et al. (ref. 29) to rank the detonation performance of explosives was used. This index is the ratio of the energy density of the expanding detonation products of an explosive to the energy density of TNT taken at sevenfold the volume of the intact explosive (ref. 25). The theoretical values of the index were derived from TIGER code (ref. 30) calculation with BKW (Becker-Kistiakowsky-Wilson) equation-of-state (EOS) parameters. The parameters of the isentropic expansion of the detonation products from the Chapman-Jouguet point which agree well with the experimental

Table 4. Equation-of-state parameters for several commercial, composite explosives (ref. 26)

	C-J parameters					JWL-EOS coefficients					
	P	D	E_o	ρ	Γ	A	B	C	R_1	R_2	ω
	Mbar	cm/ sec	Mb·cc/cc	g/cc							
ANFO	.060	0.465	.0325	0.850	2.063	0.4760	.00524	.00720	3.5	.9	.31
POURVEX	.130	0.610	.0450	1.360	2.893	3.2207	.07769	.00324	4.7	1.4	.16
EL-836	.135	0.579[a]	.920	1.520	2.775	2.8123	.02507	.01445	4.5	1.1	.20
DBA-65-T2	.120	0.540[a]	.0800	1.520	2.694	2.1467	.02157	.01295	4.3	1.4	.20
UNIGEL	.120	0.576[a]	.0510	1.262	2.49.	1.9070	.07580	.00627	4.4	1.4	.23
TELEDET	.150	0.652	.0410	1.360	2.854	3.0409	.05804	.00347	4.3	1.5	.20
AQUANAL	.055	0.370[a]	.0550	1.430	2.559	0.9123	.00407	.00746	4.4	1.0	.16

[a]These are not D_∞ values. The EOS represents the behavior in the largest charge size tested in this work.

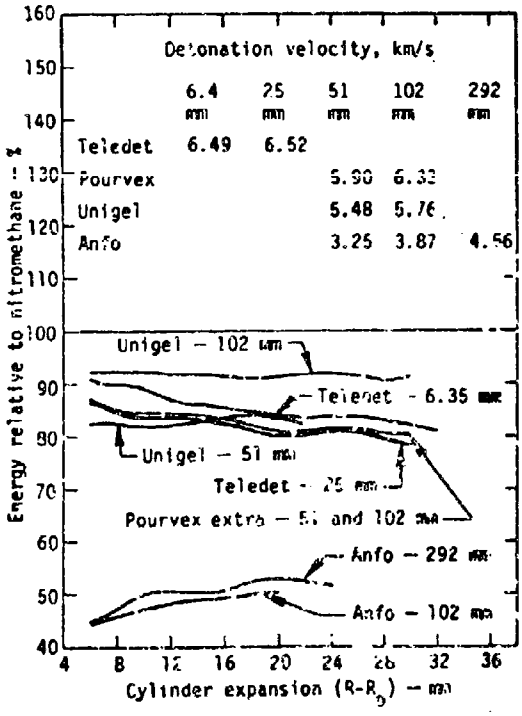


Figure 5. Relative energy of non-aluminized blasting agents (ref. 26).

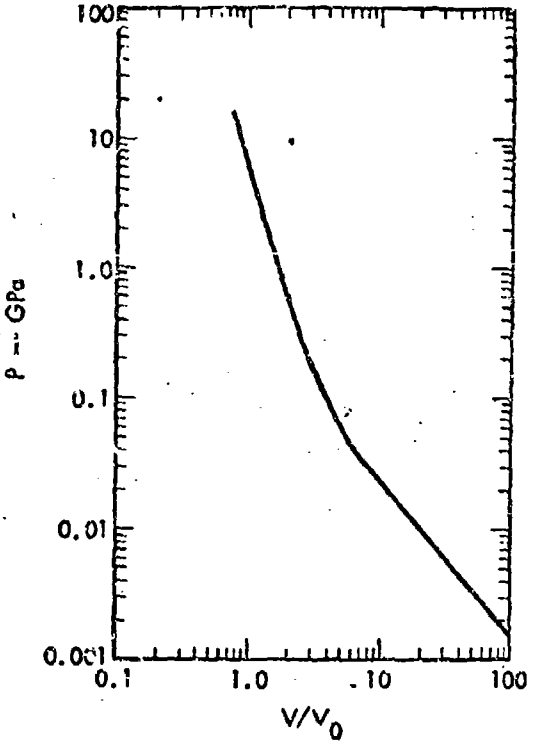


Figure 6. Release adiabat of Teledet high explosive (ref. 27).

values that were obtained from the cylinder wall expansion test. These calculations are listed in table 5.

Table 5. Energy density ratios (ref. 29)

Explosive	Initial density ρ_o (g/cc)	Theoretical (BKW) $\rho_o \Delta E_{7Vo}$ (kcal/cc	Theoretical (BKW) Ratio R_{exp}/R_{TNT}	Experimental Ratio R_{exp}/R_{TNT}
Teledet	1.40	1.06	0.69	0.68
NM	1.14	1.11	0.74	0.72
TNT	1.63	1.54	1.00	1.00
Comp B (64/36)	1.72	2.02	1.31	1.38
PETN	1.76	2.29	1.49	1.65
RDX	1.77	2.33	1.51	1.66
HMX	1.89	2.57	1.67	1.82

Minimum Air-Gap

The minimum air-gap is the separation distance across which an explosive can propagate when detonated. The air-gap or explosion-by-influence test (ref. 12) indicates that explosives with low gap values are more likely to incur propagation difficulties since the continuity of the charge can be easily interrupted. This is a variation of the card gap test.

Although the minimum air-gap has not actually been measured for Teledet, experiments have shown that this explosive slurry has to be fully interconnected to insure full detonation (ref. 1, 36). At the mine-clearing demonstration on 29 October 1975 full detonation was not achieved in a plastic hose and the explanation given suggested that an air bubble had developed in the hose which prevented the propagation to continue.

The Bureau of Mines requires that all permissible explosives must have a minimum air-gap sensitivity of at least 3

inches (7.62 cm) as measured by the airgap test (ref. 12). For the military services this is not a mandatory requirement.

Toxicity and Fume Classification

Most of the ingredients comprising Teledet are non-toxic. The only material that has a high toxicity is PETN if inhaled or ingested. If Teledet is to be used in a US military application, a medical evaluation will be required to determine if any stipulations or restrictions are needed in the handling of the material.

Also to be considered are the fumes after detonation. The fume classification is based on a measure of the undesirable toxic gases, primarily nitrogen oxides and carbon monoxide, produced by the detonation of an explosion. The fume classes were designated by the Institute of Makers of Explosives (ref. 31) and permissible explosives must not produce more than 2.5 cubic feet of poisonous gases per pound of explosive by the Bechel gage method (ref. 32). The fume class for Teledet has not been determined, but this can be estimated from TIGER calculations.

Oxygen Balance

Prior to the use of analytical codes, i.e., TIGER, the general rule of thumb for efficiency of explosives was the calculation of the oxygen balance to negative CO_2 (ref. 33, 34). A good oxygen balance implied that a detonated explosive will work efficiently without leaving uncombusted fumes to react for secondary detonation. Generally the oxygen balance of ammonium nitrate-based explosives is better than conventional explosives. The calculation for oxygen balance for Teledet indicates that it is oxygen deficient with a value of -12% in terms of negative CO_2. For comparison purposes TNT has a value of -74% CO_2 balance. With few exceptions most conventional explosives have a decidedly negative oxygen balance to CO_2.

Vibration and Settling Effects

Both types of Teledet were not subjected to the standard vibration test (ref. 4). However, a 200 g sample of each type was subjected to the effects of an air vibrator for about 24 hours. The low viscosity Teledet did show a slight change in appearance. It could not be determined if the ingredients of the explosive slurry were in any stage of separation. The high viscosity Teledet did not show any effects to that vibration.

However, when samples of both types of Teledet were stored in a magazine for approximately three months, a definite separation occurred with the low viscosity Teledet. This material separated into a clear yellowish liquid and a white residue which had settled to the bottom of the container. A short shaking period seemed to restore the appearance of the sample to its original form. The high viscosity Teledet did not display any separation.

APPLICATIONS - CONSIDERED AND PROPOSED

The applications for which Teledet has been considered and/or proposed can be separated into two categories - commercial and military - although the data generated are utilized in either category.

On a commercial basis Teledet has been designed for:

1. Oil or gas well formation fracturing
2. Rock fracturing for in-situ ore leaching
3. Oil shale fracturing
4. Explosive formation of fire lane clearances

The LLL coal gasification program (ref, 8, 9, 21, 23, 26, 27) utilized Teledet as one of a group of explosives for rock fracture studies in coal seams. Teledet was their choice for laboratory rock fracture studies solely because it performed as an "ideal" explosive in small diameters (ref, 8). Part of this program consisted of two series of experiments. One series consisted of small-scale experiments, called block experiments, where relatively small charges of ideal explosives were detonated in roughly 1.0 - 1.5 m blocks of coal. These laboratory tests were conducted at LLL and permitted careful post shot investigation of the fractured region. The other series, which were designated outcrop experiments, were conducted in an actual coal mine in an outcrop. This permitted an extension of the laboratory work to include a comparison of ideal and nonideal explosives, a closer approximation of a infinite medium, and the effects of large-scale discontinuities (ref. 23). Permeability measurements were conducted.

For comparison purposes, a brief description of each type of test is as follows. For the small-scale experiment Teledet was loaded into a plastic tube, 0.53 cm I.D., 0.025 cm thick wall, 20 cm long, capped with a 0.3 cm diameter RP-3 detonator. This assembly

was located at the bottom of a 0.63 cm diameter hole centered in one of the large blocks of coal. After the test,holes were drilled parallel to the emplacement hole in order to check permeability. In the large-scale test the Teledet charge, 5.5 m long, 0.1 m diameter and weighing 59 kg, was fired with its axis vertical and its center 15 m deep in a 26 m thick subbituminous coal seam in Kemmerer, Wyoming (ref. 27). The stemming and emplacement are shown in figure 7 while details of the emplacement are shown in figure 8. Although satisfactory performance of Teledet was obtained, LLL opted for a more powerful composite explosive to continue the program on a large-scale basis.

The potential military applications for slurry explosives such as Teledet cover a broad range. Since this material can be poured, sprayed, pumped, or foamed, and also has the ability to adhere to any surface, this permits one to be more selective in considering the potential applications. The characteristic that this explosive can be used in a fixed geometry as well as in the "loose" and/or improvised state are positive attributes. Among the potential applications are mine field clearance and neutralization, area denial, tunnel clearance, urban warfare, improvised mines, and demolition charges for structures, vehicles, trenches, and the like.

Among the first specific military applications that Teledet has been considered as a candidate for is the man-portable mine neutralization system (MANPLEX) in the exploratory development program conducted by the US Army Mobility Equipment Research and Development Command (MERADCOM) (ref. 35). In developing this capability with slurry explosives two approaches were to be investigated. One required a back-pack container while the other would be a remotely operated neutralizer. In each case the slurry explosive would be projected through a nozzle to a distance up to 150 feet. An alternative projection configuration would be to project a thin-walled tube filled with the slurry explosive to the required distance.

Subsequently a contract was awarded to Teledyne McCormick Selph by MERADCOM to conduct a series of tests using Teledet as the slurry explosive as a candidate for the MANPLEX program (ref. 36). In this effort the MANPLEX system was defined as one which could be deployed by a single individual into a suspected minefield and which would neutralize both antipersonnel and antitank mines over a linear distance of 100 feet (30.5 m) and a width of 1.5 feet (.46 m). This requirement was amended to include the opening of a path through concertina and/or barbed wire and the investigation of Teledet as a foamed explosive. This testing was supplemented by additional experiments conducted by MERADCOM (ref. 37).

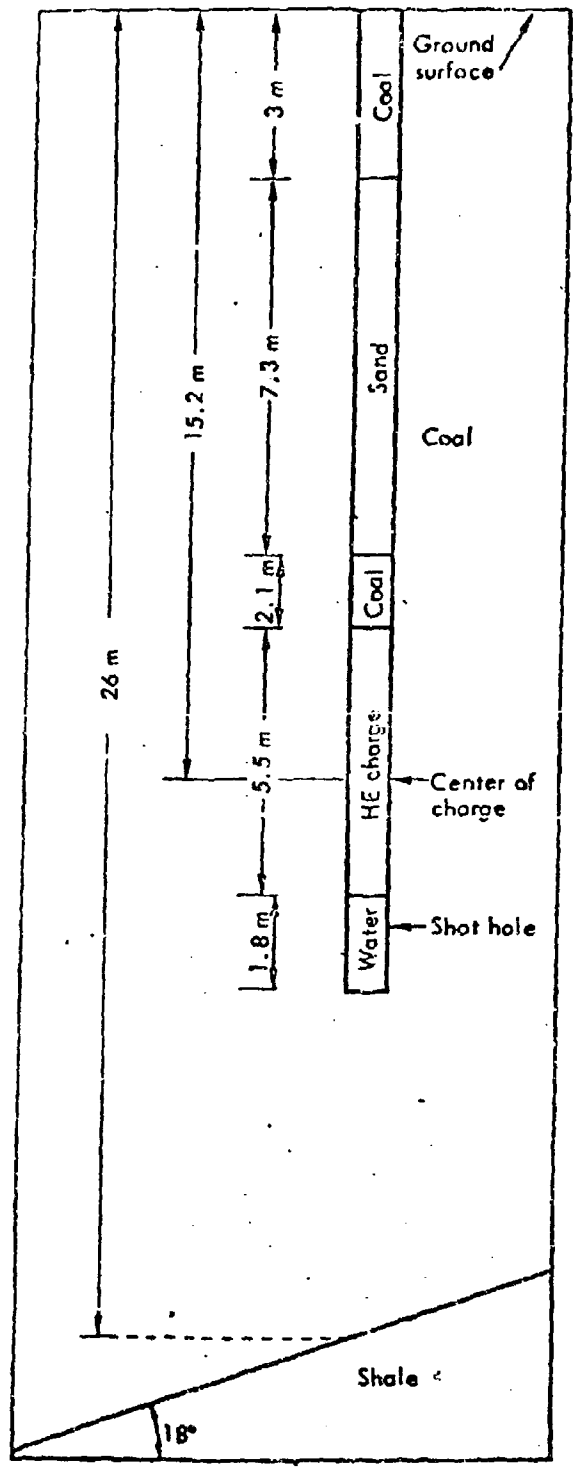


Figure 7. Stemming and emplacement of the explosive for the Kemmerer experiment (ref. 27).

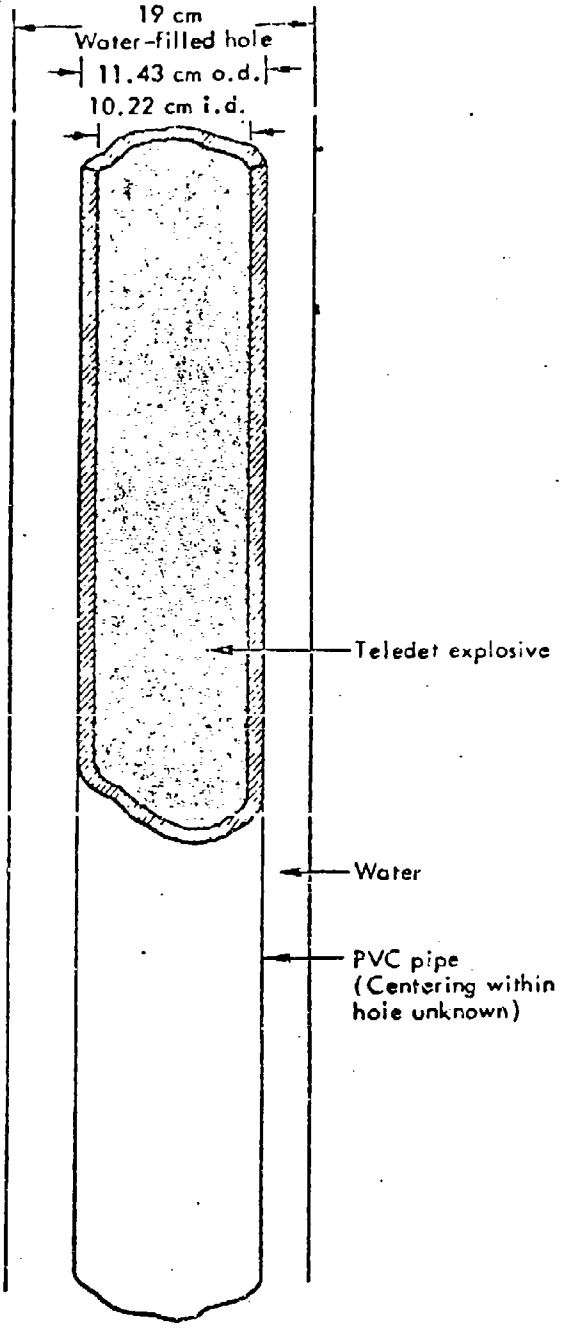


Figure 8. Detail of the explosive emplacement (ref. 27).

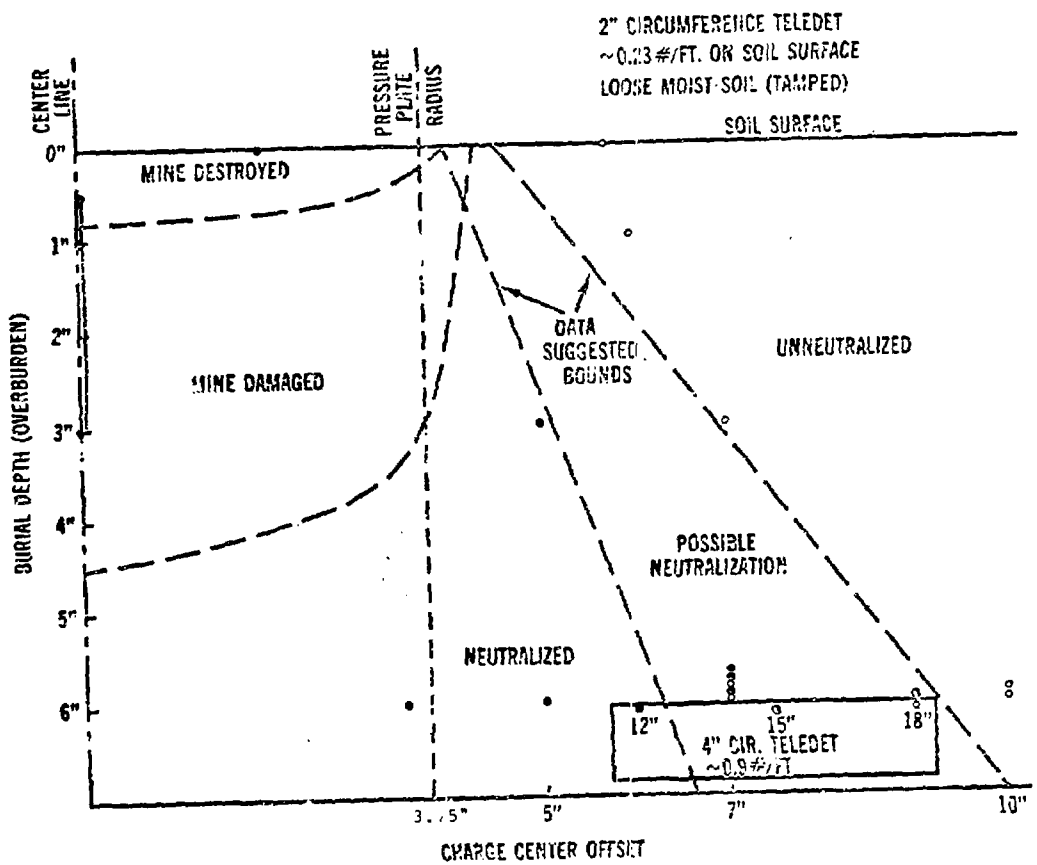


Figure 9. Depth/offset ability of Teledet with buried mines (ref. 37).

The results indicate that the spraying of Teledet was feasible although the distance goal was not achieved with the available means. Although the explosive slurry in the MANPLEX system has a tendency to break up in mid-air beyond 50 feet during spraying, this problem may be solved if the logistics of the system are modified. The ballistic deployment of an empty thin walled plastic tube to a distance of 100 feet (30.5 m) was attained. After the launch the tube could be filled with Teledet and detonated to clear a path of mines. With concertina and barbed wire the explosive effects of Teledet, in spray or in tubular configuration, did not yield satisfactory results. These wires were highly impervious and withstood breeching by those methods.

By using a suitable blowing agent and CO_2, Teledet was found to be readily foamed to approximately twice its volume. The decrease in density did decrease its propagation sensitivity, i.e., the critical detonation thickness was increased.

MERADCOM conducted depth/offset tests with buried mines using Teledet and the general pattern of results are plotted in figure 9 (ref. 37). Line charge configurations in 2 inch (5.08 cm) plastic tubes were utilized on various types of soil and offset above the ground. Additional tests on concertina and barbed wire were conducted using baling and piano wire as a means to shear or cut.

Other slurry explosives are being studied for this program and comparisons are being made on performance. The possibility of adopting a munition already developed by a foreign nation also exists.

Teledet was also considered as an alternative explosive slurry for a 6.4 SLU-FAE application under development at MERADCOM (ref. 38). A series of performance tests were conducted with Teledet in the unconfined state against antitank mines. In most of these tests Teledet was poured onto the ground in various configurations to determine the effects upon detonation on the buried mines.

A description of these tests is as follows. In one test 173.8 kg (79 lb) of Teledet was poured onto the ground in a 152.4 cm (5 ft) diameter circle. A string of five antitank mines was buried in a row every 152.4 cm (5 ft) from the edge of the explosive circle. Another row 182.88 cm (6 ft) apart was located 90° away. A third row 213.36 cm (7 ft) was located 90° from the second row. After detonation, investigation revealed that the two closest mines in the 152.4 cm and 182.88 cm rows detonated as did the closest one in the 213.36 cm row.

The second test consisted of 176.0 kg (80 lbs) of Teledet in a 154.4 cm (5 ft) diameter circle with six 304.8 cm (10 ft) radii as shown in figure 10. Each arm was made with 26.4 kg (12 lb) of Teledet. One mine was located 286.5 cm (9.4 ft) from the center equidistant from two of the ra i while another was 213.36 cm (7 ft). The other four mines ranged from 152.4 to 274.3 cm beyond the ends of the radii. Only the two mines within the 304.8 cm radius were detonated by the explosion of the Teledet.

A third test consisted of two 176 kg (80 lb) charges of Teledet in two 154.4 cm (5 ft) diameter circles 243.8 cm (8 ft) apart from each edge. One mine was placed at the midpoint. On the same center line another mine was placed 222.5 cm (7.3 ft) from the outside edge of one circle of explosive and another 152.4 cm (5 ft) from the outside edge of the other circle. Two mines were placed perpendicular to the midpoint mine, one at 499.9 cm (16.4 ft) and the other 180° away at 749.8 cm (24.6 ft). None of the mines was damaged upon simultaneous detonation of the two 176 kg charges. The mines were buried an average depth of 20.5 cm (12 in.).

The cutting or shearing ability of Teledet was demonstrated in the set-up as shown in figure 11. In this experiment 291 grams of Teledet were placed in a thin strip 3.81 cm (1.5 in.) wide, 127 to 3.81 cm (.5 to .75 in.) thick across a 38.1 x 38.1 x 2.54 cm (15 x 15 x 1 in.) 1020 mild steel plate. The plate formed a bridge across two supports. Another experiment with a 1.27 cm thick plate was also conducted. In both cases a clean cut was obtained.

The report which includes these experiments has not yet been published (ref. 38). However, officially Teledet was not selected as the back-up explosive for the SLU-FAE application since the results indicated that the explosive power of Teledet did not meet the requirements for the application.

Teledet is being considered as a candidate explosive in two other applications. One is with a lane-proofing application being developed by MERADCOM and the other is an underwater mine neutralization application just being undertaken by the Navy. Details on each application have not been formalized as of this report.

Projected Costs

Estimates for large-scale production of Teledet are difficult to project due to the unknown inflationary factors which affect the economy.

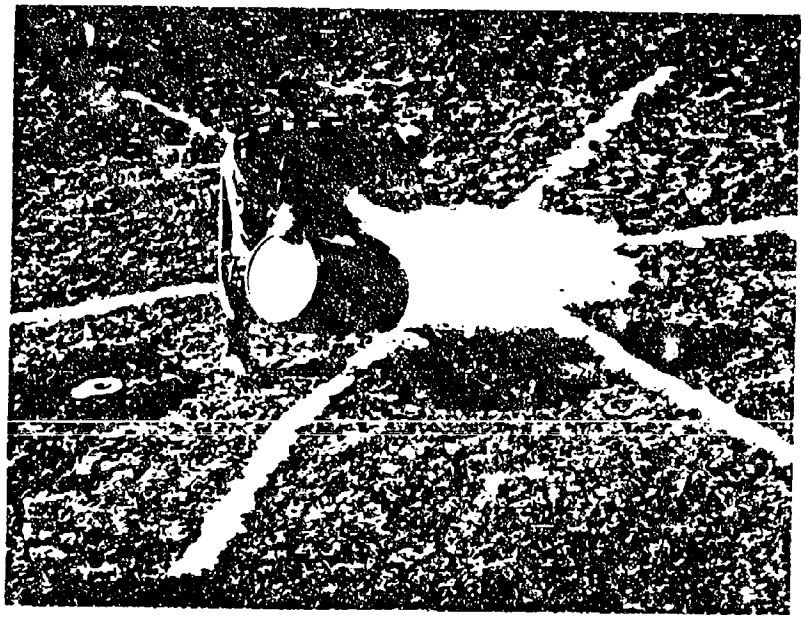
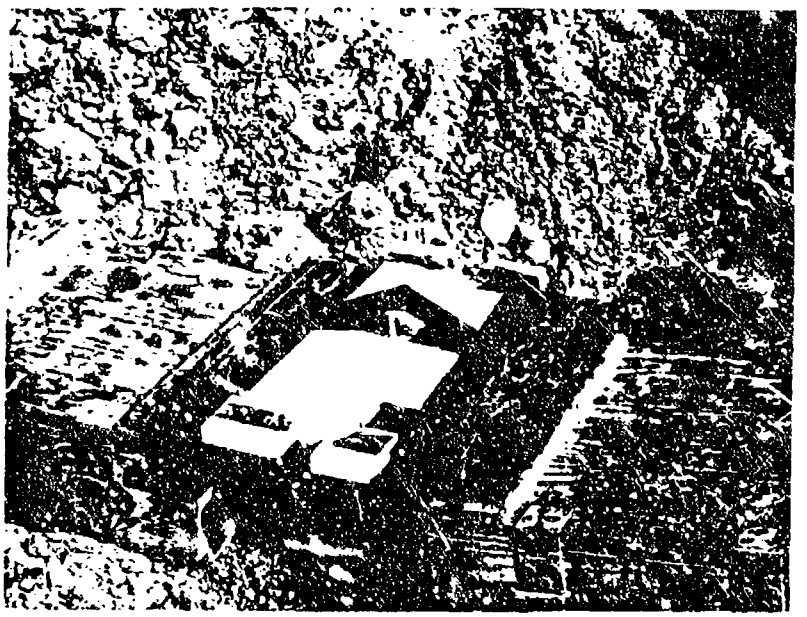
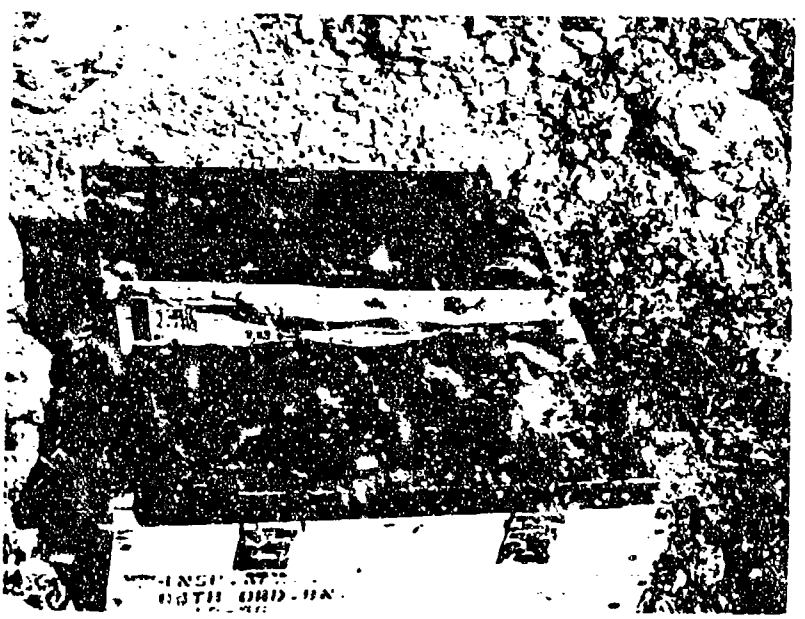


Figure 10. Sun-ray test on antitank mines with Teledet (ref. 30).



a. Before



b. After

Figure 11. Cutting or shearing experiment with Teledet.

On a general basis, for a 2.27×10^6 kg/yr (5,000,000 lb/yr) production schedule the price for Teledet is approximately 40% above the price for PETN purchased from a supplier and 30% above the price of PETN manufactured in a completely integrated PETN facility.

In a cost study conducted in September 1974 by the manufacturer (ref. 40) costs were determined which can be scaled to 1978 dollars. Estimates of $1.32/lb (2.91/kg) for Teledet manufactured with purchased PETN and $0.85/lb ($1.87/kg) for Teledet manufactured in a completely integrated PETN facility were obtained for a production level of 5,000,000 lb/yr.

On a comparison basis, approximate costs for conventional explosives as of June 1978 are as follows:

	Cost per pound	Cost per kilogram
TNT	$0.65	$1.43
RDX, Class 1	1.60	3.53
HMX	6.25 - 11.40	13.78 - 25.13
Comp B	1.25	2.76
PETN	1.55 per 300 lb	3.42
Superfine PETN	1.90 per 150 lb	4.18
Teledet	3.00 - 3.50 (small lots)	6.61 - 7.72

CONCLUSIONS AND RECOMMENDATIONS

In determining the characteristics or properties of an explosive, there is a strong tendency, from a safety or performance point of view, to categorize the characteristics as advantages or disadvantages as compared to other known explosives. Subsequently when that explosive is a candidate material for an application these "good and/or bad points" are balanced, or "traded off", in a direct relationship depending upon the performance required in that application. From this are determined the background information tests in order to obtain the interim qualification of the explosive in that application.

Therefore based on the information generated to date, the advantages of Teledet are as follows:

1. Very good safety characteristics

2. Good chemical and thermal stability (for a slurry explosive)

3. Attractive rheological properties for easy emplacement

4. Acts as an "ideal" explosive-propagates in small diameters

The disadvantages of Teledet are:

1. The metal acceleration capability of Teledet is only about 75% that of TNT.

2. The separation of the ingredients in low viscosity Teledet

3. The limitations of a water-based slurry

4. Higher cost compared to other slurry explosives

(NOTE: The minimum air-gap separation can be considered both as a "good" point for safety and "bad" for requiring continuity of material to obtain complete detonation.)

The applications with which Teledet has been considered to date use that explosive in the "loose" state on the ground or in a hose. It has been designated as a slurry explosive since it has a very small critical diameter which in turn stipulates that the reaction zone is very short. In explosives with small critical diameters most of the reaction is completed in the primary reaction zone leading to high detonation pressures. It is not known whether Teledet combines the properties of a slurry explosive and a blasting agent in slurry form, although it acts as an ideal explosive. In blasting agents significant reactions may occur behind the C-J plane since more of this energy can be released in the expanding gas phase of the explosion.

For the mine neutralization applications the metal acceleration ability may not be the only power or strength characteristic needed. Tests should be conducted in determining the cratering ability of this explosive slurry on or below the surface as a function of thickness and the effectiveness compared to other explosives. From this pressure and impulse measurements as a function of distance would be parameters to be studied. The impulse, or the area under

the pressure-time curve is another means of measuring the power of the explosive. Analytically this could be calculated by extending the TIGER calculation for the energy density beyond the seven times the original volume and determine the increase, if any, in total detonation pressure.

Experimentally the underwater evaluation of Teledet would produce additional performance data. The underwater shock and bubble energy measurements (ref. 4, 5) can characterize the shattering action and the heaving action of the explosive relative to a standard explosive.

If an increase in the cratering ability, underwater shock and/or bubble energy of Teledet is required for a specific application, an aluminized form of Teledet could be developed (ref. 46).

In summary the following information has been amassed on Teledet which will assist in obtaining an interim qualification for *any* application. The *mandatory* requirements (ref. 4) which have been completed are:

1. Impact sensitivity
2. Large-scale gap sensitivity
3. Friction sensitivity
4. Electrostatic sensitivity
5. Self-heating
6. Detonation velocity

The performance and background data that have been obtained are as follows:

1. Determination of critical diameter
2. Cylinder expansion
3. Projectile impact

If Teledet is considered as a serious candidate for an application it is recommended the the following areas be investigated and/or tests be conducted:

1. Detonation velocity as a function of temperature, i.e., the detonability of Teledet when frozen

2. Cratering ability as a function of charge diameter

3. Compatibility and reactivity with standard metals and materials

4. Performance as a function of temperature extremes

5. Effect of exposure to moisture, heat

6. Vibration and/or separation of ingredients

7. Additional thermodynamic data, i.e., heat of explosion, thermal expansion, etc.

8. Card gap as a function of temperature and diameter

9. Minimum air-gap propagation

10. Neutralization, i.e., will acetone kill the explosive?

11. Environmental effects

The costs projected for large-scale production of Teledet do not appear to be prohibitive. Depending upon the application and an estimated requirement, a judgment would have to be made whether the cost of the explosive compared to the total cost of the end item would warrant the need for another explosive.

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