BuMines OFR 73-82

PB82-215765

DEVELOPMENT OF AN AUTOMATIC FIRE PROTECTION SYSTEM FOR SURFACE VEHICLES

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

by
LEASE "AFEX", INCORPORATED
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FINAL REPORT - VOLUME I

Contract No. HO262049

January 31, 1981

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16. Abstract (Limit: 200 words)

Automatic fire protection systems were designed, installed, and tested to protect three basic types of surface mining equipment: a large, rubber-tired front-end loader; a large and a small blast-hole drill; and a haul truck. The systems were tested after several months of installation and successfully discharged. The systems proved to be practical from the standpoint of protection, reliability, ease of maintenance, and cost effectiveness.

17. Document Analysis a. Descriptors

Minin

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Surface mining equipment
Front-end loader
Large blast-hole drill
Small blast-hole drill
Haul truck
Protection
Reliability
Ease of maintenance
Cost effectiveness

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FOREWORD

This report was prepared by Lease "AFEX", Inc. under USBM Contract number H0262049. It was administered under the technical direction of the Twin Cities Mining Research Center with Mr. W. H. Pomroy acting as Technical Project Officer. Mr. Richard A. Field, Jr. was the contract administrator for the Bureau of Mines. The report is a summary of the work recently completed as part of this contract during the period May 16, 1978 to January 13, 1981. This report was submitted by the author on January 31, 1981.

We gratefully acknowledge the help and cooperation of everyone who participated in the investigation, design data collection and testing of the system.

We particularly want to thank both the Amax Coal Company and the Drummond Coal Company for their interest and help.

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FINAL REPORT - VOLUME I

DEVELOPEMENT OF AN AUTOMATIC FIRE

PROTECTION SYSTEM FOR SURFACE VEHICLES

USBM CONTRACT HO 262049

MAY 16, 1978

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

WASHINGTON, D. C.

FINAL REPORT - EXECUTIVE SUMMARY

SUMMARY AND CONCLUSION

SUMMARY

Development and application of automatic fire protection systems for specific types of surface mining equipment was initiated under two Department of the Interior's Bureau of Mines Contracts. The first was Contract SO 251046, "Development and Testing Services of a Fire Protection System for Coal Augers", March 1975 - October 1975. The second was Contract S 3360490, "Development, Installation, and Testing Services for an Automatic Point Type Thermal Sensor, Fire Protection System on a Mining Dozer", September 1975 - August 1976. After sucessfully completing these two contracts, USBM - Lease "AFEX", Inc. Contract HO 262049 was issued to conduct further investigation of Automatic Fire Suppression Systems for use on surface mining equipment.

The objective of this contract was to develope and in-mine test a reliable automatic fire protection system for various types of surface mining vehicles. Design parameters included ability to withstand the extremes of operational and environmental conditions found in this type application; provide positive protection for both operator and vehicle; be relatively simple to inspect and maintain; and have a cost effectiveness justifying it's use.

A review of typical equipment used in open-pit coal mining indicated that blast hole drills, rubber-tired loaders, and haulage trucks constituted a major cross-section of various types of equipment used. Accordingly, visits were made to typical open-pit mines and arrangements made with two mines to furnish machines for prototype installations.

The system design included investigating the use of Halon 1301 and dry chemical either jointly or individually, as conditions dictated. Because the dry chemical has an adverse effect of electrical switch gear and rotating machinery (such as motors and generators), Halon 1301 offered excellent fire suppression possibilities as it is non-corrosive with respect to electrical equipment. Also, in enclosed

cabs and/or machinery houses, it is non-toxic in volumetric ratios of seven (7) percent or less.* Visibility is unobscured as it is colorless when discharged. However, provision must be made to prevent or minimize introduction of fresh air at discharge. When the Halon-air ratio drops below 2.5 percent, the fire suppression value decreases.

When the equipment design of certain machines such as large loaders or trucks is considered, the ability to limit air inclusion is impossible. As a result, dry chemical is the only practical fire suppressant. Because the flow or enveloping effect of dry chemical is limited, the discharge has to be directed by means of tubing and nozzles so as to totally flood the interior of the engine-transmission compartments. Both size and safety guards on machines made manual application of dry chemical with portable fire extinguishers impossible or impractical. Also, unless dry chemical is applied simultaneously to all areas, fire could spread from one area to another. Thus, local application would only offer temporary protection.

After a detailed analysis of the physical and operating characteristics of the three types of equipment under study, systems were designed for each. For the large blast hole drill, a combination Halon 1301 and dry chemical system was used. For the small blast hole drill, only dry chemical was used because of the open machinery deck. On the large front end loader, only dry chemical was used because of inability to limit fresh air dilution to a Halon 1301 system.

CONCLUSION

1. From tests conducted both at initial installation and after almost 12 months field operation, it is apparent the installed systems have the capability to withstand all operational conditions as well as environmental conditions. There were no failures in the physical hardware on any of the machines. All successfully fired after prolonged field usage.

2. As designed and installed, the respective systems on each type of

(NFPA Code 12A, paragraph 2-1.1.3)

machine evidenced the ability to suppress (as much as was possible to demonstrate) fires likely to occur. One actual fire occurred on a 675 loader owned by Falcon Coal early in 1978 and was successfully extinguished by the "AFEX" system identical to that installed on the Drummond loader.

3. These systems by virtue of their quick sensing and reaction to fire would afford good operator protection.

4. All systems are relatively unsophisticated in respect to maintenance and servicing.

5. Installation is relatively simple and does not cause excessive downtime for retrofit installation.

6. The fire suppression systems as installed do not interfere with normal operation or servicing of the basic machine. Routine maintenance of the machine does not require removal of any part of the fire protection system and does not require de-activating the system. Thus, fire protection is provided during maintenance periods when welding or cutting present other than normal hazards.

7. Several mines on the Minnesota Mesabi Iron Range were visited to observe the manual type fire suppression systems installed on various make trucks. It was reported to us that on several occasions, recently, trucks equipped with manual systems had burned because the operator paniced and failed to actuate the manual discharge. Early warning of a fire before it became visible to the operator could probably have reduced the size of the fire and perhaps reduced the panic of the operator.

Most mines contacted expressed strong interest in conversion of the manual systems. There were a number of options that were asked for in the conversion kit. These included:

a) Basic heat sensing with warning lights in operator's cab,

b) Automatic engine shut down,

c) Full conversion for both early warning and automatic firing of system,

d) Built-in delay of firing to allow truck to be stopped before dry chemical is discharged. It was stated some fear of obscuring operator vision existed,

e) Replacement of flat spray side type nozzles with cone spray nozzles,

f) Replacement of existing hoses with steel tubing for powder distribution,

g) Integration of existing manual "dash actuators" into automatic control.

From our investigation, it appears the basic conversion present no problem. The other options appear to be feasible; however, they will add some cost to the conversion.

I. INTRODUCTION

The objective of this contract was to develop and in-mine test a reliable automatic fire protection system for various types of surface mining vehicles. It must by able to withstand the extremes of operational and environmental conditions found in this type application. It also must provide positive protection for both operator and vehicle. It must be relatively simple to inspect and maintain and have cost effectiveness justifying it's use.

A review of typical equipment used in open-pit coal mining indicated that blast hole drills, rubber-tired loaders, and haulage trucks constituted a major cross-section of various types of equipment used. Accordingly visits were made to typical open-pit mines and arrangements made with two mines to furnish machines for prototype installations. (See Exhibit A and J.)

The system design included investigating the use of Halon 1301 and dry chemical either jointly or individually, as conditions dictated. Because dry chemical has an adverse effect on electrical switch gear and rotating machinery (such as motors and generators), Halon 1301 offered excellent fire suppression possibilities as it is non-corrosive with respect to electrical equipment. Also, in enclosed cabs and/or machinery houses, it is non-toxic in volumetric ratios of seven (7) percent or less.* Visibility is unobscured as it is colorless when discharged. However, provision must be made to prevent or minimize introduction of fresh air at discharge. When the Halon-air ratio drops below 2.5 percent, the fire suppression value decreases.

When the equipment design of certain machines such as a large loader or truck is considered, the ability to limit air inclusion is impossible. As a result, dry chemical is the only practical fire suppressant. Because the flow or enveloping effect of dry chemical is limited, the discharge

*NFPA Code 12A, paragraph 2-1.1.3.

has to be directed by means of tubing and nozzles so as to totally flood the interior of the engine-transmission compartments. Both size and safety guards on machines make manual application of dry chemical with portable fire extinguishers impossible or impractable. Also, unless dry chemical is applied simultaneously to all areas, fire could spread from one area to another. Thus, local manual application will only offer temporary protection.

All of these types of equipment have fire hazard potential and source/cause. These are: hydraulic lines, fuel lines, high heat sources such as exhaust manifolds and blowers, and electrical spark hazard. In addition each is subject to hazardous dust collection.

II. DESIGN AND INSTALLATION

B. Large Blast Hole Drill

A Bucyrus-Erie Model 61R Blast Hole Drill was selected as a typical machine of its class. While there are several other manufacturers of large blast hole drills, most of the designs as to operator's cab, machinery house, and electrical gear are similar. Overall size is also roughly equivalent. One user of such a drill, AMAX Coal Company in Evansville, Indiana, was contacted. Agreement was reached to allow us to install a combination Halon dry chemical system on one of their drills at the Ayershire Mine (see AMAX letter dated September 9, 1975, Exhibit "A").

The initial investigation involved visiting the mine and observing the 61R Drill for two purposes:

1) Determine normal operating temperatures in all areas to be protected, and
2) Determine actual physical dimensions for engineering study.

This was done on July 7, 1976. The operating temperatures were determined by the use of "Teletemp" surface temperature recorders (see Exhibit "B"). The temperatures within the drill structure were as shown on Exhibit "C". Outside ambient air temperature was in the 90's. The temperatures found indicated that operating temperatures were fairly close to those found in other mining equipment such as tractors and loaders.

The physical dimensions and location of various components within the machinery house were taken and are as shown in Exhibit "C" and in the table, Exhibit "D". Since the volume of the various motors, switch gear cabinets, and compressors constituted less than 10% of the overall volume (and allowing for some leakage of air through deck openings), it was decided to calculate the required Halon for design purposes on the gross volume.

Using the calculation procedure as designated by the National Fire Protection Association and as used by the Walter Kidde Company, determination of the hardware was made. These calculations are shown in Exhibit "E".

It was determined that fifty (50) pounds of Halon 1301 would be needed for an induced concentration of 6%. This figure was selected to allow for a sustained concentration of 3 + %, which is the desired percentage.

Concentration hazards are established in NFPA Standards #12A. It also requires a concentration of at least 2.5% to effectively control combustion. Thus the problem resolves itself down to first, control of fresh air intake at time of discharge, and second, inducement of sufficient Halon 1301 to maintain a 3-4% concentration with initial induction not to exceed safety limits for personnel in immediate area.

Having determined the correct poundage of Halon 1301 required, the next step was control of fresh air intake at time of system discharge. Because the drill structure is pressurized to exclude dust, the pressurizing fan must be stopped before the Halon is discharged. Normal fan run down is 40-50 seconds. It was decided to utilize an adjustable delay relay in the sensor circuit to first kick out the pressurizing fan and delay firing of the Halon system long enough for the fan to run down. Such a relay is the Agastat Adjustable Relay. This is a ruggedly built unit and can be adjusted from 2-50 second delay.

It was also decided after discussion with the AMAX people that it would be highly advantageous to knock out both the main motor-generator set and the pressurizing fan at the initial point of fire detection. What this means, is that when the initial fire alarm is sounded, the entire drilling operation is stopped including drill head, hoist, and travel motors. (This is in addition to the pressurizing and cooling fans.) This procedure insures that even though the operator abandons the drill at the sound of the alarm or is incapacitated, the drill will automatically shut down. It can not be restarted until a manual reset button is activated. The wiring diagram for the Halon control panel is shown in Exhibit "Q".

A warning light and bell actuate when the sensors picked up fire heat. A warning horn would sound when the Halon system discharged. The delay relay has to be excited for the full duration of the delay, otherwise,

it will reset itself. This means that if the delay were set for 50 seconds and a temporary hot air flow existed, closing the heat sensor, the warning light would go on. However, if the heat were only due to a temporary cause and was not sustained for over 50 seconds, the system would not discharge but simply warn the operator of some malfunction to be investigated. This guards against false alarms.

By way of example, on or about July 1, 1978, the sight glass on the rear compressor broke and sprayed hot water/antifreeze on the adjacent sensor. The non-locking circuitry as mentioned above allowed an alarm to be sounded, but prevented discharge of the Halon 1301 agent. The mine was therefore spared labor, material, and downtime expenses of a recharge. At the same time, the operator was made aware of a malfunction in the engine house.

The transformer room at the rear of the engine house did not lend itself to Halon, as the entire floor is a grating and there is no way to control the air flow. Also, there is no switch gear or other electrical equipment in this room which could be adversely effected by the dry chemical. Thus, an automatic dry chemical system would be ideal in this area. The installation is shown in the drawing Exhibit "F" and "F-1". Specifications of the "AFEX" automatic system are shown in Exhibit "G".

B. Small Blast Hole Drill

The 30R drill was selected for this size machine test design. Again, agreement was reached with AMAX Coal Company to use one of their 30R drills located at their Ayershire Mine. (See AMAX letter September 9, 1975 Exhibit "H".)

Initial investigation involved visiting the mine and physically examining the 30R drill. The major fire area is the open engine compartment. Because it is used to drill the coal seam, considerable coal dust accumulates over the entire machine. It was apparent that a dual "AFEX" system would give excellent coverage to the entire machine, including the engine compartment, operator's cab, and powder magazine. Standard "AFEX" point type thermal sensors* were used together with electric manual switch discharge capabilities. The installation is on drawing Exhibit "I".

*Standard "AFEX" Sensor

Probe Type Thermostat	-	snap disc
Stainless Steel Body	-	1" long
Closing Temperature	-	300°F ± 8°F
Opening Temperature	-	250°F ± min
Mounting Thread	-	3/8 - 18 PFT
Leads	-	6" long #18 AWG, 200°C TFE, nickle clad copper wire
Shock Test	-	MIL-S-202D
Vibration Test	-	MIL-S-202D
Ambient Range	-	-65°F to 600°F

Hermetically sealed with epoxy reinforced glass seal

C. Large Rubber Tired Front End Loader

Large rubber tired loaders are being used in more mines every day. While their production is high they do present fire protection problems different than a large crawler tractor or truck.

The basic design concept is an articulated vehicle with the engine in the rear frame. The operator's cab is mounted on top of and at the front of the rear frame. In the event of fire in the engine compartment, the operator would have little, if any, early warning. Also, the unit utilizes a large number of hydraulic circuits. These are high pressure and operate at high temperatures. This means that in the event of a leak or break in a hose, the oil is already close to the flash point and requires little in the way of additional heat source for ignition.

The Clark 675 Loader is the largest of this class vehicle. Fire protection adequate for this machine would more than cover all other makes and models. The operator's cab is about twelve feet above ground and egress is by means of a ladder between the two halves of the machine. Thus, early suppression of fire is required to assure the operator time to get off the machine. Because of its size, replacement of this loader is limited, and in the event of damage by fire, replacement or repair parts are subject to delay. This could cause serious disruption of coal production, as the loader is a key piece of equipment.

The Drummond Coal Company of Jasper, Alabama was contacted and agreement reached to install an "AFEX" automatic fire suppression system on one of their 675 loaders. See Exhibit "J". On the 30th and 31st of July, 1976, the mine at Tuscaloosa, Alabama, where the loader was working, was visited with Mr. W. H. Pomroy of TCMRC.

It was determined four (4) "AFEX" systems would be required to provide the coverage desired. This machine carries over 400 gallons of hydraulic oil and 500 gallons of fuel oil. It is also equipped with an automatic grease system. The forward portion of the rear frame is a maze of hydraulic hoses, pumps, and filters. Two Cummins engines provide power and are located immediately behind the hydraulic complex.

The system design is shown on drawings Exhibits "K", detail "A", "B", and "C". Point type thermal sensors were used, one (1) in the front frame, six (6) over the hydraulic area, and seven (7) in the engine compartment. All four systems were tied together electrically to fire simultaneously so as to totally flood the entire machine. The control boxes were located as shown in the installation drawings, allowing good access by the operator.

The piping was of necessity unbalanced. In the past it was thought that if a system contained sections that had over a 3:1 length ratio, unequal powder discharge would result. In order to justify the use of unbalanced piping, we constructed a test frame the approximate size of a medium size tractor. Tests were made as described in Exhibit "L" - "Distribution Test on "AFEX" Fire Suppression System". The test results showed that when using steel tubing and bending rather than using elbows to change direction, no apparent inequality was evidenced.

D. Automatic Fire Warning System

Agreement was obtained from the AMAX Coal Company people at the Ayershire Mine to use a Mack Tractor bottom dump coal hauler unit for installation of a prototype automatic fire warning system. This initial prototype consists only of heat sensors which will give audible warning to the operator in the event of fire. The operator then will have to manually trigger the fire protection system which is already installed on the haul unit.

Accordingly three (3) heat sensors, N/O -300° F closing temperatures were installed in the engine-transmission area of the tractor. These were wired to a control box which contained a 95 DBL horn as well as a battery source. When the sensor closes, the horn sounds, alerting the operator to:

a) Stop Vehicle
b) Actuate fire protection system
c) Dismount from tractor

III. ON-VEHICLE TESTS

In addition to the testing of the electrical circuitry and visual inspection of piping and tubing networks, actual discharge tests were conducted on the four machines involved in this contract. No actual fires were ignited: however, a low temperature heat source (propane torch) was used to activate the systems on the 675 rubber-tired front end loader and the warning system on the bottom dump coal hauler. The other machines were fired electrically.

A. Large Blast Hole Drill

It was agreed that a simulated firing of the "AFEX" dry chemical system covering the transformers in the rear section of the drill would suffice. One of the heat sensors was activated by applying a low heat source to it. The system functioned as designed and the triggering machanism actuated, driving the piercing rod down into the opening that the CO_2 pressuring bottle would normally be screwed into. This, for all practical purposes, proved the ability of the sensors to first, detect the heat, and secondly, complete the firing circuit and actuate the triggering mechanism.

While Halon systems have been used for many years in static applications such as computer rooms, the installation of this Halon system on the 61R blast hole drill is one of the first, if not the first, of such installations. Therefore, it was decided to conduct full scale concentration tests on this portion of the 61R drill fire protection system.

Arrangements were made for Mr. L. B. Magnus, Special Product Manager, Southern Region, Walter Kidde and Company, Inc., to conduct the concentration tests. Tests of the 1301 Halon systems were carried out using 1211 Halon as the test agent. This is as specified in NFPA 12A and by U.L., F.M., and F.I.A. A concentration by weight of 80% 1211 is used. Induced concentrations referred to are indicated directly in % Halon 1301 by volume. Three (3) monitoring points were used, one in the operators cab, one in the hydraulic pump room, and one in the main engine-house. These are shown on Exhibit "M". The meter used was a strip recording type meter.

It should be noted that no attempt was made to close-up the many openings in the engine-house structure, except to close the doors and cover two damaged louvers. In addition to the pressurizing fan inlet duct, there were many cable openings and similar holes in the floor plate of the engine-house. It was felt, however, that this condition was typical, and, that in order to have a realistic test, conditions would be the same as those anticipated in the field.

The test conducted on Seprember 28, 1976 resulted in the data shown in Exhibit "N". This indicated too high (over 10%) an induced concentration in the operators compartment. The concentrations at point #2 and point #3 began as anticipated, (approximately 5%) and dropped rapidly after 1-1/2 to 2 minutes. Between 2% and 3% was maintained for 3 to 5 minutes, which would have been sufficient to snuff out a surface fire. Deep seated fires would need a longer "soak" period.

Because of the excessive concentration in the operators cab in test #1, a second test was made on October 19, 1976. A smaller nozzle was installed in the operator cab area. The test showed a decided improvement, with a maximum concentration of 8.4%: a rapid drop to about 7% occurred, which is an acceptable level of human exposure, as per NFPA 12A. This data is shown on Exhibit "O".

Again, reasonable concentrations were experienced in the hydraulic pump area and the main engine-house. The hydraulic pump area showed some increase to about 8% induced. This was probably due to increased pressure and resultant discharge rate caused by throttling down the nozzle orifice in the operators cab. The engine-house concentration peaked out at 6.1% and held above 2% for almost 3 minutes.

Analysis of these test firings suggested further modification so as to increase time of higher concentration in engine room for better "soak" period. Accordingly a second Halon 1301 tank of 20# capacity was piped into system and wired so as to discharge approximately 90 seconds after

B. Small Blast Hole Drill

After completeing the installation and preliminary checks on the dual "AFEX" system installed in the 30R drill, arrangements were made to conduct test firing of systems on Wednesday, September 29, 1976. Accordingly, the test was made on Wednesday morning.

Discharge was caused by jumping the sensor circuit and using the system battery power. Full discharge was accomplished in approximately 16 seconds. Coverage is shown on slides in Section VII. As may be seen, a covering ranging from 1/16" to as much as 1/4" in some areas was developed. Principle coverage was obtained around the engine, hydraulic tanks, pumps, filters, and fuel tank. The test indicated nozzle placement was correct. Observers present indicated they felt the discharge would handle any fire that might occur.

C. Large Rubber-Tired Front End Loader

Sunday, August 1, 1976 discharge tests were made on the four unit "AFEX" system on the 675 loader at the Drummond Coal Company Mine outside Tuscaloosa, Alabama. The systems were wired so that all four units fired simultaneously, completely blanketing the loader on discharge. A low temperature heat source was used to actuate one of the sensors in the engine area.

Upon application of the heat, discharge was obtained. It extended over approximately 15 seconds with all four extinguishers shells being completely emptied. Excellent coverage was obtained, with only minor adjustment of one or two nozzles indicated.

While coverage was total and thorough, excess collection or deposit of grease and oil can present serious fire hazards above those normally associated with this type equipment. It is recommended that periodic steam cleaning be conducted as the situation warrants.

D. Automatic Fire Warning System

Following the installation of the sensors, wiring, control box, and horn, heat was applied to the right front sensor. After approximately 6 seconds application of the flame from a butane cigarette lighter, the system went into alarm causing the horn to sound in the operator's cab. About 10 seconds after the heat was removed from the sensor, the horn stopped sounding, indicating the sensor had reset itself and opened the circuit.

This fire warning system does give the operator some advance warning in case of fire. However, firing the system is still dependent on some one being present, not panicing, and/or not failing to activate the fire suppression system.

IV. CONCLUSIONS

1. From tests conducted both at initial installation and after almost 12 months field operation it is apparent the installed systems have the capability to withstand all operational conditions as well as environmental conditions. There were no failures in the physical hardware on any of the machines. All sucessfully fired after prolonged field usage.

2. As designed and installed, the respective systems on each type of machine evidenced the ability to suppress (as much as was possible to demonstrate) fires likely to occur. One actual fire occurred on a 675 loader owned by Falcon Coal early in 1978 and was successfully extinguished by the "AFEX" system identical to that installed on the Drummond loader.

3. These systems by virtue of their quick sensing and reaction to fire would afford good operator protection.

4. All systems are relatively unsophisticated in respect to maintenance and servicing. (See Sections VIII and IX.)

5. Installation is relatively simple and does not cause excessive downtime for retrofit installation.

6. The fire suppression systems as installed do not interfere with normal operation or servicing of the basic machine. Routine maintenance of the machine does not require removal of any part of the fire protection system and does not require de-activating the system. Thus, fire protection is provided during maintenance periods when welding or cutting present other than normal hazards.

7. Several mines on the Mesabi Iron Range in northern Minnesota were visited to observe the Ansul manual type fire suppression systems installed on various make trucks. It was reported to us that

on several occasions, recently, trucks equipped with manual systems had burned because the operator paniced and failed to actuate the manual discharge. Early warning of a fire before it became visible to the operator could probably have reduced the size of the fire and perhaps reduced the panic of the operator.

Most mines contacted expressed strong interest in conversion of the manual systems. There were a number of options that were asked for in the conversion kit. These included:

a) Basic heat sensing with warning lights in operator's cab,
b) Automatic engine shut down,
c) Full conversion for both early warning and automatic firing of system,
d) Built-in delay of firing to allow truck to be stopped before dry chemical is discharged. It was stated some fear of obscuring operator vision existed,
e) Replacement of flat-spray tank side type nozzles with cone spray nozzles,
f) Replacement of existing hoses with steel tubing for powder distribution,
g) Integration of existing manual "dash actuators" into automatic control.

From our investigation of manual systems observed on Euclid R 170 and WABCO M 85 and M 100 trucks, it appears the basic conversion presents no problem. This would involve mounting heat sensors and wiring through equipment battery to a warning light and/or bell in operator's cab.

The other options appear to be feasible; however, they will add some cost to the conversion.

V. COST EFFECTIVENESS

The following chart indicates the approximate cost of each machine as well as the estimated cost of our designed system:

MACHINE	APPROXIMATE MACHINE COST	FIRE PROTECTION SYSTEM COST (INSTALLED)	% OF CAPITAL INVESTMENT
Large Blast Hole drill	$1,000,000	$7,000	0.7%
Small Blast Hole drill	$100,000	$2,500	2.5%
Large Loader	$1,200,000	$5,000	0.4%
Retrofit Warning System	$100,000 to $600,000	$ 700 to $2,400	0.4% to 0.7%

Usage of some type of automatic fire suppression system is undoubtedly going to increase rapidly due to:

1) Government regulations,
2) Economic factors such as high insurance premiums,
3) Decreased availability of fire insurance.

This contract has shown that practical systems are available at a cost that is acceptable.

VI. EXHIBITS

AMAX COAL COMPANY
A DIVISION OF AMAX INC.
MIDWEST AREA OFFICE
853 SOUTH HEBRON AVENUE — BOX 5434 EVANSVILLE, INDIANA 47715
(812) 479-8771

September 9, 1975

Mr. W.D. Lease, President
Lease Aflex, Inc.
1300 Paddock Drive
Raleigh, NC 27609

Dear Mr. Lease:

As we discussed during your recent visit, we have been doing a survey of our fire protection needs. While these needs vary due to the numbers and types of equipment, we are very interested in exploring the use of Halon 1301 as a protection system for our new 61-R Bucyrus-Erie drill at our Ayrshire Mine.

We would be willing to make this drill available to you for the design and installation of a Halon 1301 system on a no-charge basis to us. This would let us evaluate the possibilities of design and also to check the reliability of such a system.

If this system proves feasible we believe there would be several applications on other pieces of our equipment that we might consider.

Yours Through Safety

AMAX COAL COMPANY

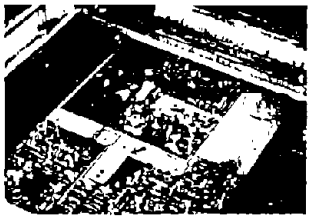
Ben T. Spears

Ben T. Spears
Asst. Safety Director

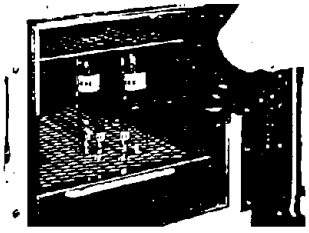
BTS/dt

EXHIBIT "A"

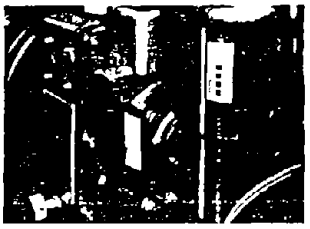
telatemp temperature recorders



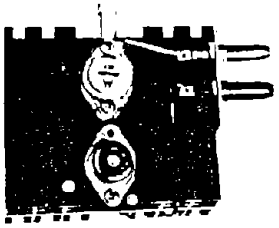
Telatemp™ affixed to PC board assembly reveals board temperature during all phases of flow soldering operation.



Exposed Telatemp ™ provides assurance that temperature reached level necessary for proper sterilization.



Product Warranty Protection – Telatemp™ tells manufacturer when specified temperature limits have been exceeded by user.



Hot Spots located at critical points on this test jig aid in determining component power dissipation and efficiency of heat sink.

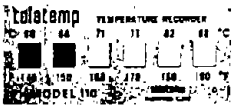
LOW COST, ACCURATE, PERMANENT RECORDS OF SURFACE TEMPERATURES

Telatemp Temperature Recorders contain one or more sealed temperature sensitive silver-colored increments. Each increment has a rated value in °F and/or °C. As each finely calibrated increment is exposed to its rated value, it turns permanently and irreversibly black. Response time for this reaction is less than one second. Accuracy is ±1%. Telatemp adheres to any clean dry surface. The exposed Telatemp may be removed and filed for subsequent reference. Telatemp will withstand thermal cycling, solvents and water and can be stored indefinitely.

EASY TO USE

1. Remove protective backing

2. Apply Telatemp™ to any clean dry surface



3. Sensing increment turns black at rated value

SELECTABLE TEMPERATURE INCREMENTS IN FAHRENHEIT AND CENTIGRADE

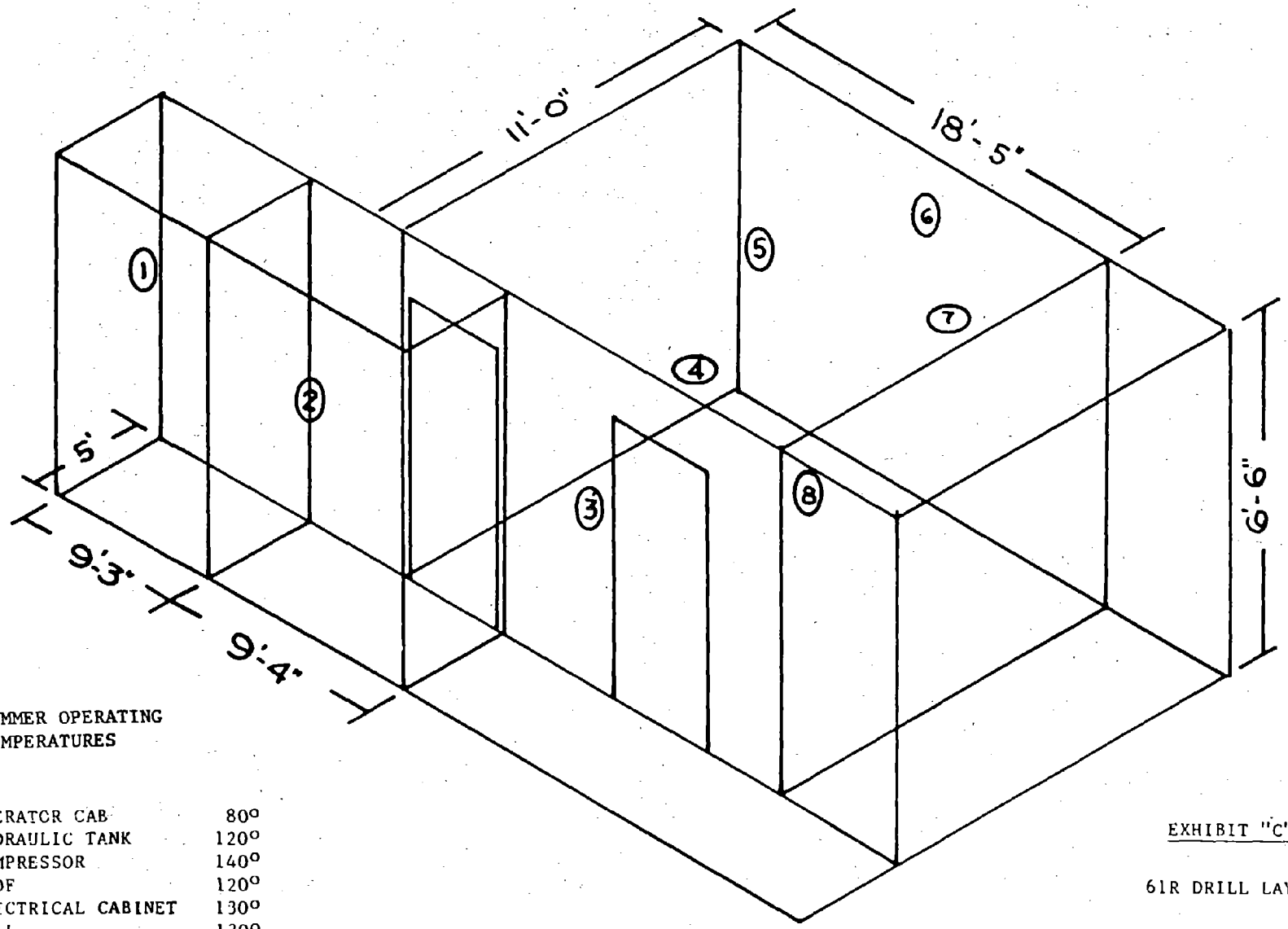
Telatemp temperature increments are available in 10° steps from 100°F to 500°F (or °C equivalent). These increments are available in a wide range of configurations as shown below.

Standard Configuration No.		MODEL 110 RANGE A (Models 310 & 330)			RANGE B (Models 310 & 330)		
1	°F	100	110	120	130	140	150
	°C	38	43	49	54	60	66
2	°F	140	150	160	170	180	190
	°C	60	66	71	77	82	88
3	°F	180	190	200	210	220	230
	°C	82	88	93	99	104	110
4	°F	220	230	240	250	260	270
	°C	104	110	116	121	127	132
5	°F	260	270	280	290	300	310
	°C	127	132	138	143	149	154
6	°F	300	310	320	330	340	350
	°C	149	154	160	166	171	177
SPECIAL HIGH TEMPERATURE CONFIGURATIONS							
7	°F	350	360	370	380	390	400
	°C	177	182	188	193	199	204
8	°F	390	400	410	420	435	450
	°C	199	204	210	216	224	232
9	°F	435	450	465	480	490	500
	°C	224	232	241	249	254	260

ORDERING INFORMATION: **Model 110** – *Order any of standard configurations No. 1 through No. 9 (includes six increments covering both Ranges A and B), i.e. Model 110-4 for 220°F through 270°F.* **Models 310 & 330** – *Order any standard configuration No. 1 through No. 9 in Range A or Range B (three increments). Specify as Model 310-1-A (or B).* **Hot Spot** – *Order any one increment shown above, i.e.: "Hot Spot 280" for 280°F. Hot Spot and Model 310 are available in °F only.* **Models 505, 550 & DIP-410** *are available only in the configurations shown.* NOTE: *Due to changes in materials used for recording above 350°F, Telatemp Models 110-7, 110-8 and 110-9 are white with gold increments.*

EXHIBIT "B"
31

Lease Afex's letter of authorization to reprint the Telatemp Recorder specifications as given in the attached brochures or any other printings thereof, dated September 28, 1981.



SUMMER OPERATING TEMPERATURES

1)	OPERATOR CAB	80°
2)	HYDRAULIC TANK	120°
3)	COMPRESSOR	140°
4)	ROOF	120°
5)	ELECTRICAL CABINET	130°
6)	WALL	130°
7)	M-G SET	130°
8)	REAR WALL	150°

EXHIBIT "C"

61R DRILL LAYOUT

61 R DRILL - VOLUME CALCULATIONS

1.	Operator's Cab 5' x 9'3" x 6'5"	=	300 Ft.^{3}
2.	HYD. Pump Room 5' x 9'4" x 6'5"	=	300
3.	Machinery House 11' x 18'5" x 6'6"	=	1315.6
		TOTAL	1917.6 Ft.^{3}

Equipment in Machinery House:

A. Low Voltage and Resistor Cabinet
B. High Voltage Cabinet
C. 200 H.P. Motor
D. Belt Guard
E. Compressor Air Filters
F. Compressor
G. M-G Set
G-1 Control Cabinet
H. Belt Guard
I. 200 H.P. Motor
J. Transfer Cabinet
K. Compressor Air Filters
L. Compressor
M. Hydraulic Oil Tank
M. Hydraulic Pump

360 PSIG HALON 1301 SYSTEM
CALCULATION ESTIMATE SHEET

CLIENT: LEASE "AFEX", INC.
FOR: AMAX COAL COMPANY

DRAWING NO. L-
SHIPPING ORDER:
DATE: 8/04/76
BY:

HAZARD	DIMENSIONS	VOLUME OR AREA	FLOODING FACTOR	HALON CONCENTRATION		NOZZLES			TOTALS	
				ACTUAL	DESIGN	FLOW RATE	QUAN.	TYPE	FLOW RATE	LBS. HALON REQD.
Mach. house	18'5"x11'x6'5"	1316 F^3	0249		6%	34	1	F	3.4	34
Hyd. Pump Rm.	9'4"x5'x6'5"	300 F^3	0249		6%	.8	1	F	.8	8
Opr. Cab	9'3"x5"x6'5"	300 F^3	0249		6%	.8	1	F	.8	8
QUANTITY OF HALON 1301 DELIVERED _____ LBS.							TOTALS		5.0	50

$\frac{2381}{2381 + 340\ (2721)} = .875$ X 161 = 140.9 + 199 = 239.9

$\frac{\quad}{+} =$ X 161 = + 199 =

$\frac{\quad}{+} =$ X 161 = + 199 =

$\frac{\quad}{+} =$ X 161 = + 199 =

NOZZLE AT POINT	C	E	F										
TOTAL REMAINING PRESS. TO WORK WITH	239.9	239.9	239.9										
MINUS PRESSURE LOSS THRU PIPE	16.7	14.7	14.7										
EQUALS SUB TOTAL PRESSURE	223.2	225.2	225.2										
ELEV. CORRECTION ± .68 #/FT.	-3.4	-3.4	-3.4										
TOTAL REMAINING PRESS. AT NOZZLE	219.8	221.8	221.8										
DISCHARGE RATE	12.4	12.6	12.6										
ULLAGE CORRECTION FACTOR	1.18	1.18	1.18										
SPECIFIC RATE	14.6	14.9	14.9										
FLOW RATE	3.4	.8	.8										
ORIFICE SIZE	.629 #21	.302 #10	.302 #10										
NOZ. PIPE THD. SIZE	3/4"	3/4"	3/4"										
PART NUMBER								EXHIBIT "E"					

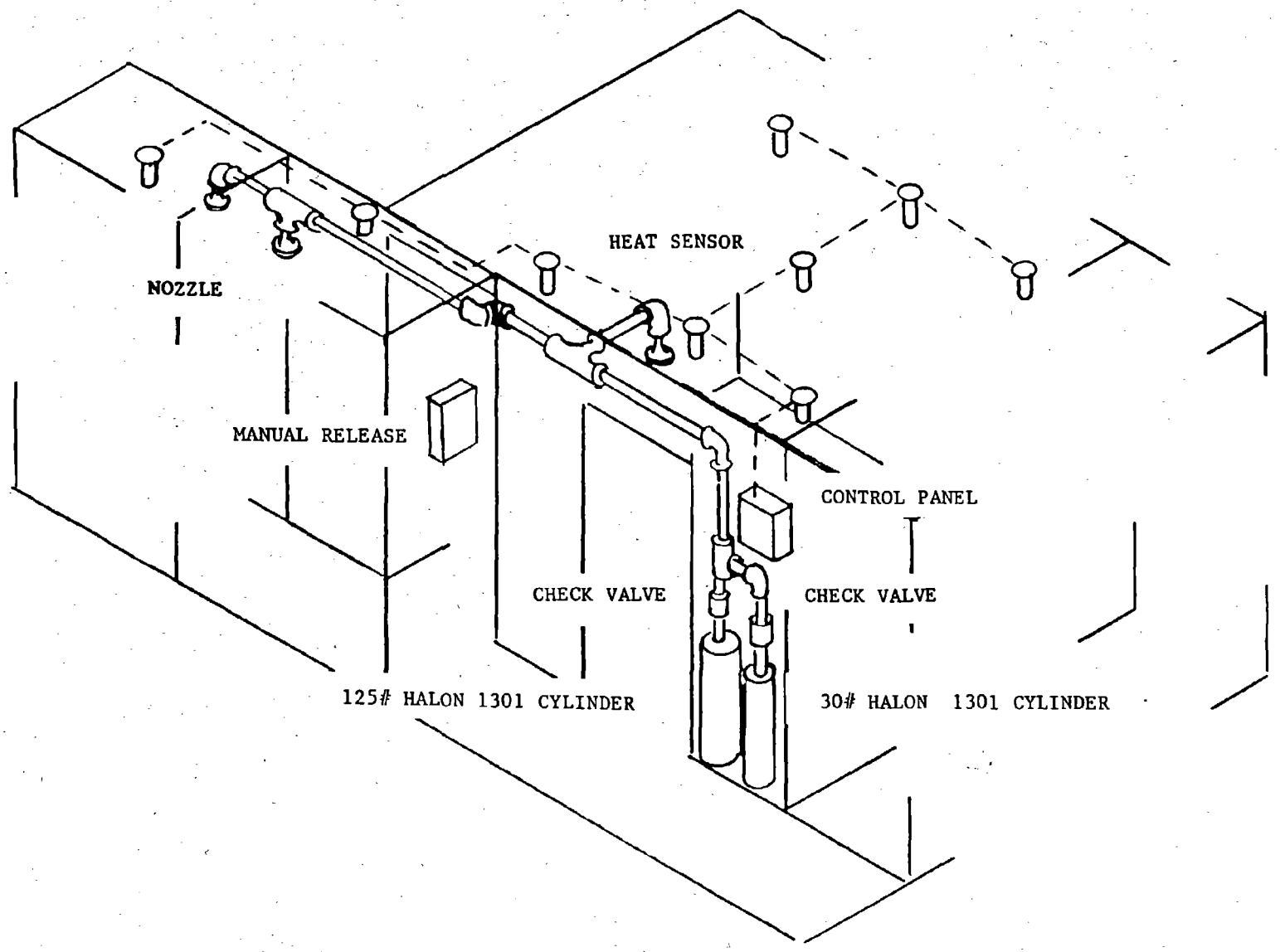


EXHIBIT "F"

61R HALON SYSTEM

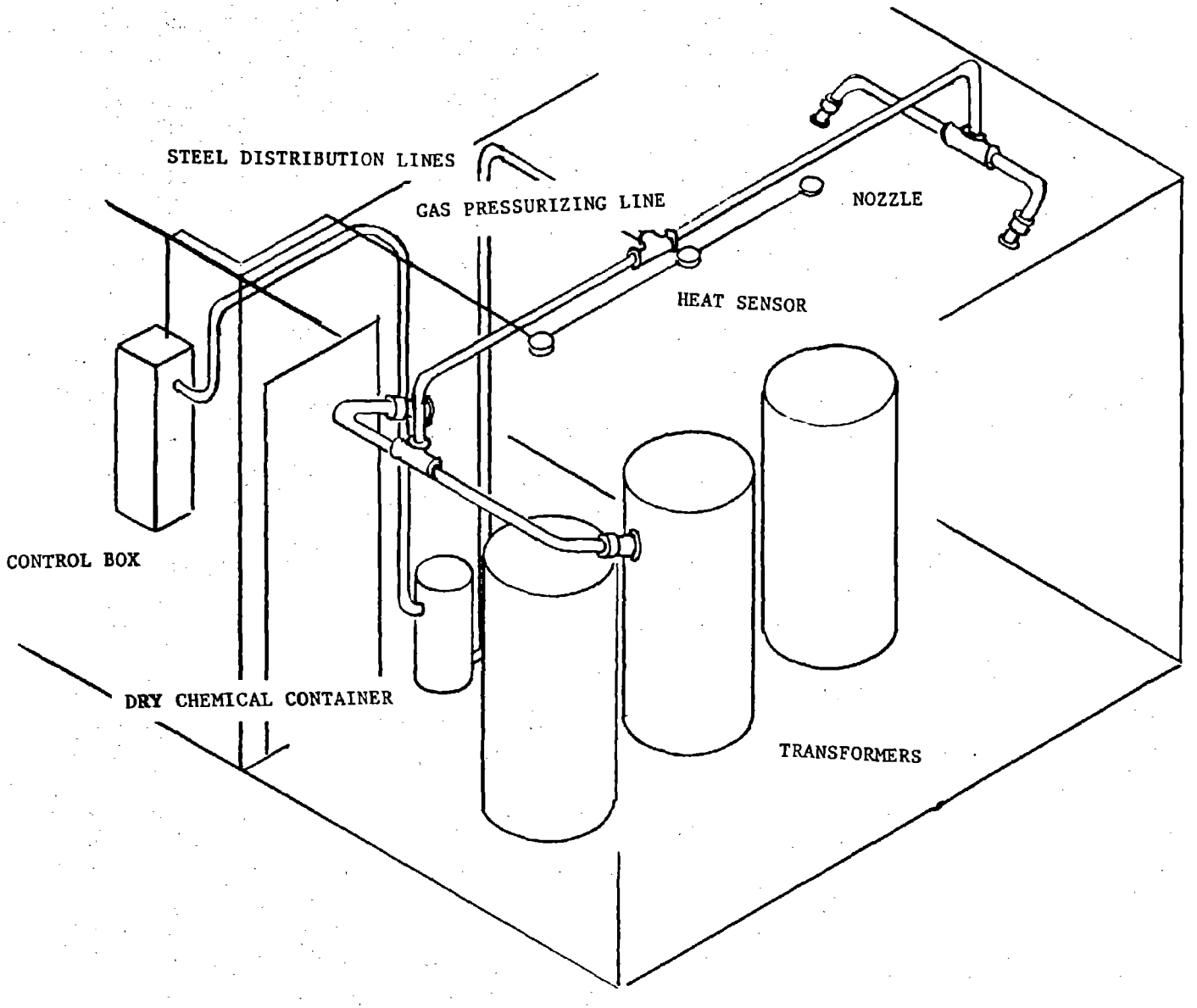


EXHIBIT F-1

61R TRANSFORMER ROOM PROTECTION

LEASE AFEX INC.

705-A Pershing Road
Raleigh, North Carolina 27608
(919) 833-2986
(919) 876-2271

TECHNICAL SPECIFICATIONS

1. SQUIB	
Safe current	one (1) ampere
Firing current	over two (2) amperes
charge	0.125 grams Boron Potassium Nitrate
Twin ignition circuits	
Temperature range	-65°F to +160°F
Temperature and humidity (MIL-810-method 507)	100% humidity at 160°F
Shock	40 G's
Acceleration (MIL-810-method 513.1)	12 G's in all axis
Vibration	5-3000 Hz from 0.25" double amplitude to 15 G's
Jolt test	MIL-300
Jumble test	MIL-301
40' Drop test	MIL-302
Salt fog test	MIL-810-method 509
Fungus test	MIL-810-method 508
2. SQUIB HARNESS	
Temperature range	-65°F to +220°F
Conductors (MIL-W-16878/1)	tin plated copper
Connector	four (4) pin Bendix with locking collar
3. SENSOR	
Contact arrangement	SPDT
Close	300 +/- 7°F
Open	275 +/- 7°F
Ambient temperature range	-65°F to +450°F
Shock (MIL-S-202D)	100 G's
Vibration (MIL-S-202D)	5-2000 Hz to 20 G's
Hermetically sealed	MIL-S-202D-method 112.A
Wire leads (MIL-W-16878)	tinned copper, Teflon 20 AWG, 400°F
Case material	6061 Aluminum

EXHIBIT "G"

TECHNICAL SPECIFICATIONS - Page 2

4. TRUNK WIRE	
Temperature range	-85° F to +550° F
Conductors (Type E-MIL-W-16878/4A)	Nickel plated copper
Primary insulation	TFE Teflon
Skived tape	TFE Teflon
Protective braid	36 AWG stainless
Outer jacket	PFA Teflon
Resistant to	diesel fuel, hydraulic oil, lube oil and grease, water, sunlight
5. FIRING MECHANISM	
Composition	330 brass 360 brass 303 stainless
Tested to	4,000 psi
Seals	Buna-N o-rings
Seal lubricant	silicone grease
Manual override	
Inside diameter	1.000"
Stroke	0.500"
6. EXTINGUISHER	
Charge	28.5# A:B:C powder
Non-pressurized	
Side cartridge operated	
Internal gas tube	
Pressurizing gas	CO_2 (standard) N_2 (low temperature)
Field refillable	
7. TUBING	
Type	JIC welded
Composition	Steel
Dimensions	0.500"OD x 0.039" Wall 0.750"OD x 0.045" Wall

EXHIBIT "G"

TECHNICAL SPECIFICATIONS - Page 3

8. TUBE FITTINGS

Vibration resistant	
Non-flared type	
Seal composition	Buna-N
Bursting strength	10,000 psi
Installation	Positive stop; no torque adjustment

9. NOZZLES

Composition	Cadmium plated steel
Spring cap cover	
Spray pattern	150^{o} cone
Effective range	Eight feet (8')

EXHIBIT "G"

AMAX COAL COMPANY
A DIVISION OF AMAX INC.
MIDWEST AREA OFFICE
653 SOUTH HEBRON AVENUE — BOX 5434 EVANSVILLE, INDIANA 47715
(812) 479-8771

September 9, 1975

Mr. W. D. Lease, President
Lease Aflex, Inc.
1300 Paddock Drive
Raleigh, NC 27609

Dear Mr. Lease:

Further to your recent visit at which time we discussed your Afex system, we would be interested in having you install such a system on one of our 30-R, B-E drills on a no-charge basis.

This installation would give us a chance to measure the valve of a piped automatic dry chemical system for fire protection on this type drill. If this system proves effective we would be interested in looking at further applications.

Yours Through Safety,

AMAX COAL COMPANY

Ben T. Spears

Ben T. Spears
Asst. Safety Director

BTS/dt

EXHIBIT "R"

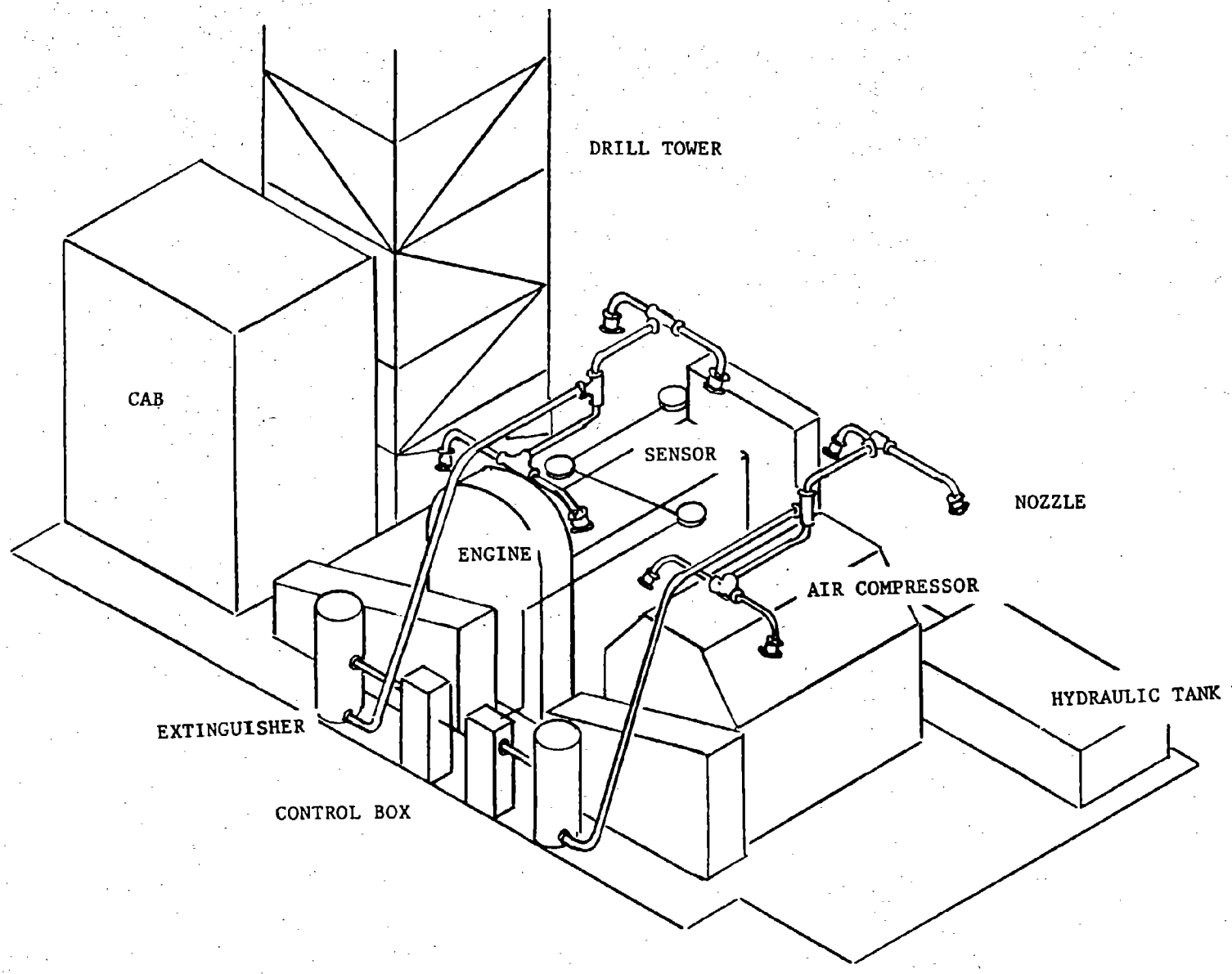


EXHIBIT I

30R DRILL SYSTEM

P.O. Box 1549
Jasper, Alabama 35501

Telephone (205) 387-0501
Telex: 5-9768 Drummond Japr

THE
DRUMMOND
COMPANY

Mr. W. D. Lease, President
Lease Aflex Inc.
1300 Paddoch Drive
Raleigh, NC 37609

Dear Mr. Lease:

As we discussed during your recent visit, we would be very interested in having you install the Afex Fire Suppression System on our 675 Michigan Loader on a no charge basis.

This would give us both a chance to evaluate the system on this machine.

If the system proves satisfactory, we would certainly be interested in looking at further application.

Sincerely,

Morris Stanford

Morris Stanford
Purchasing Agent

EXHIBIT "J"

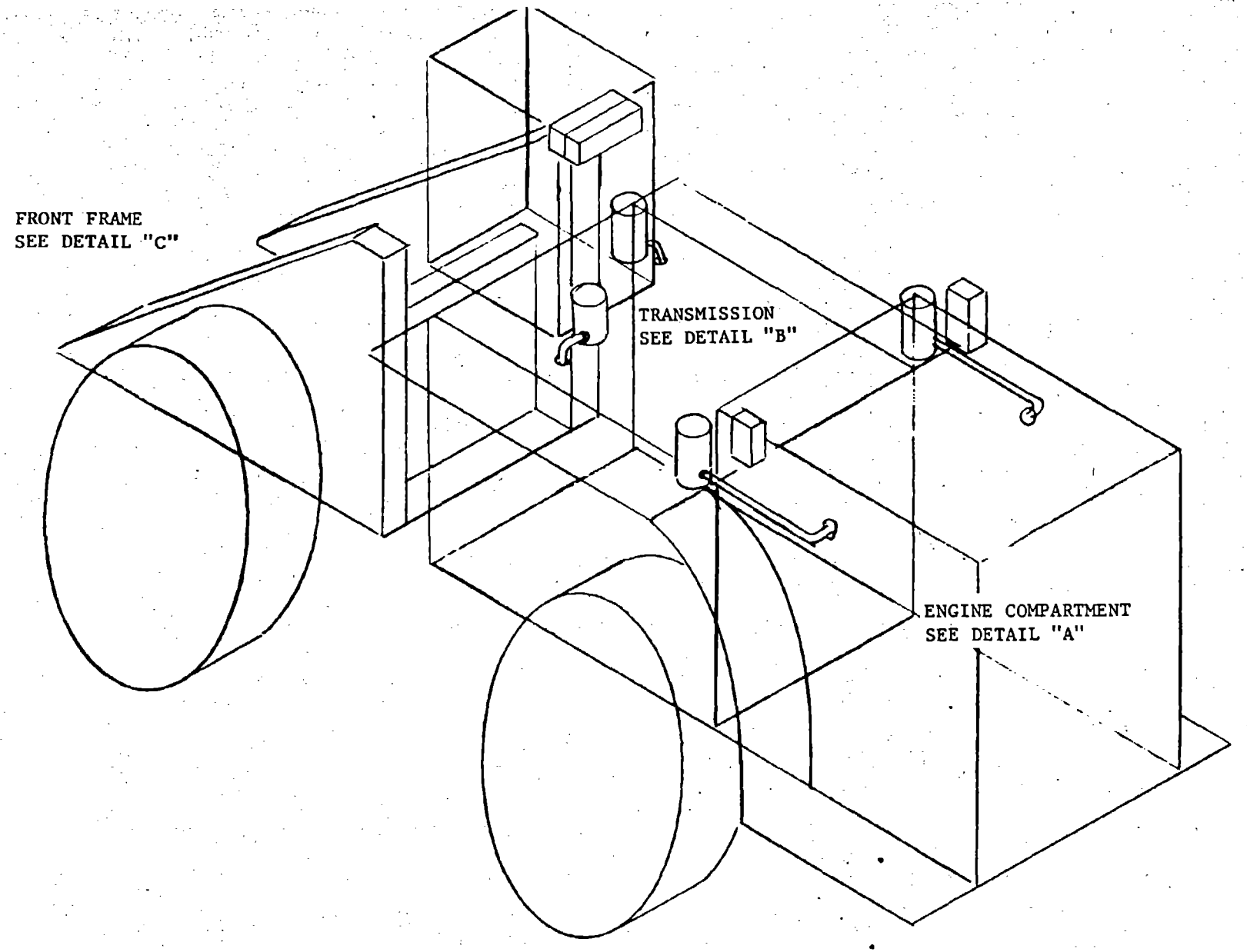
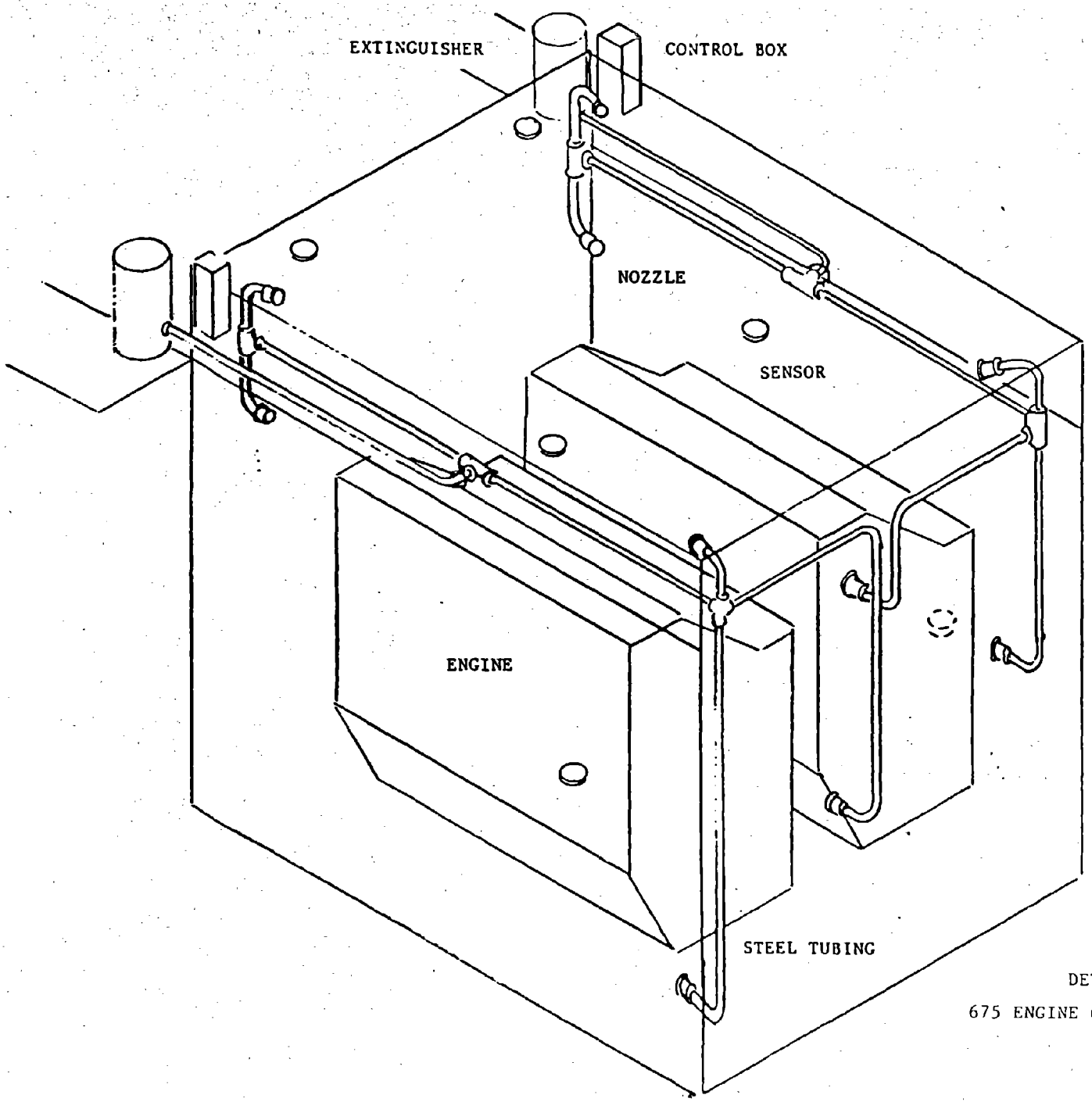


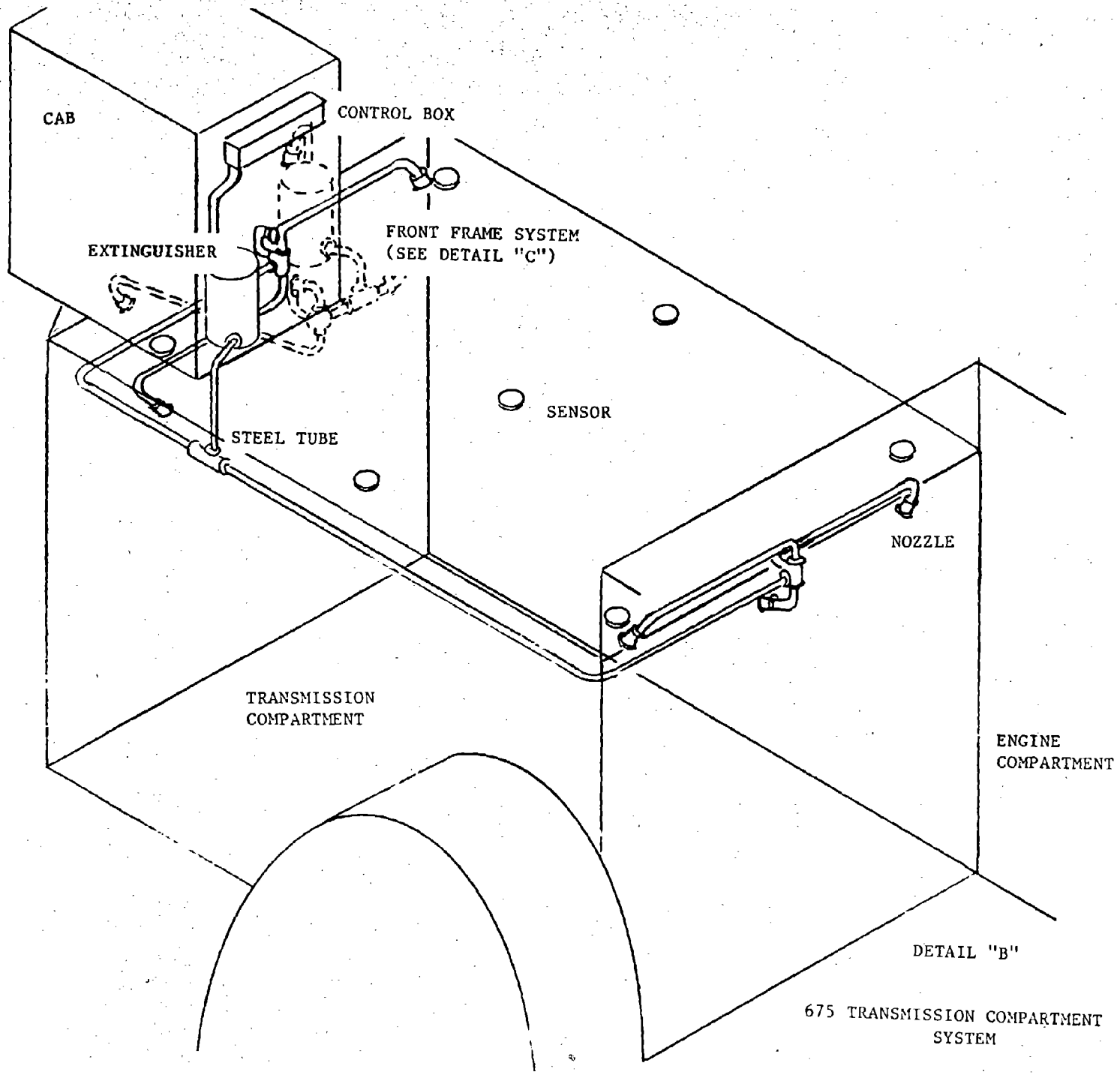
EXHIBIT K

675 LOADER SYSTEM

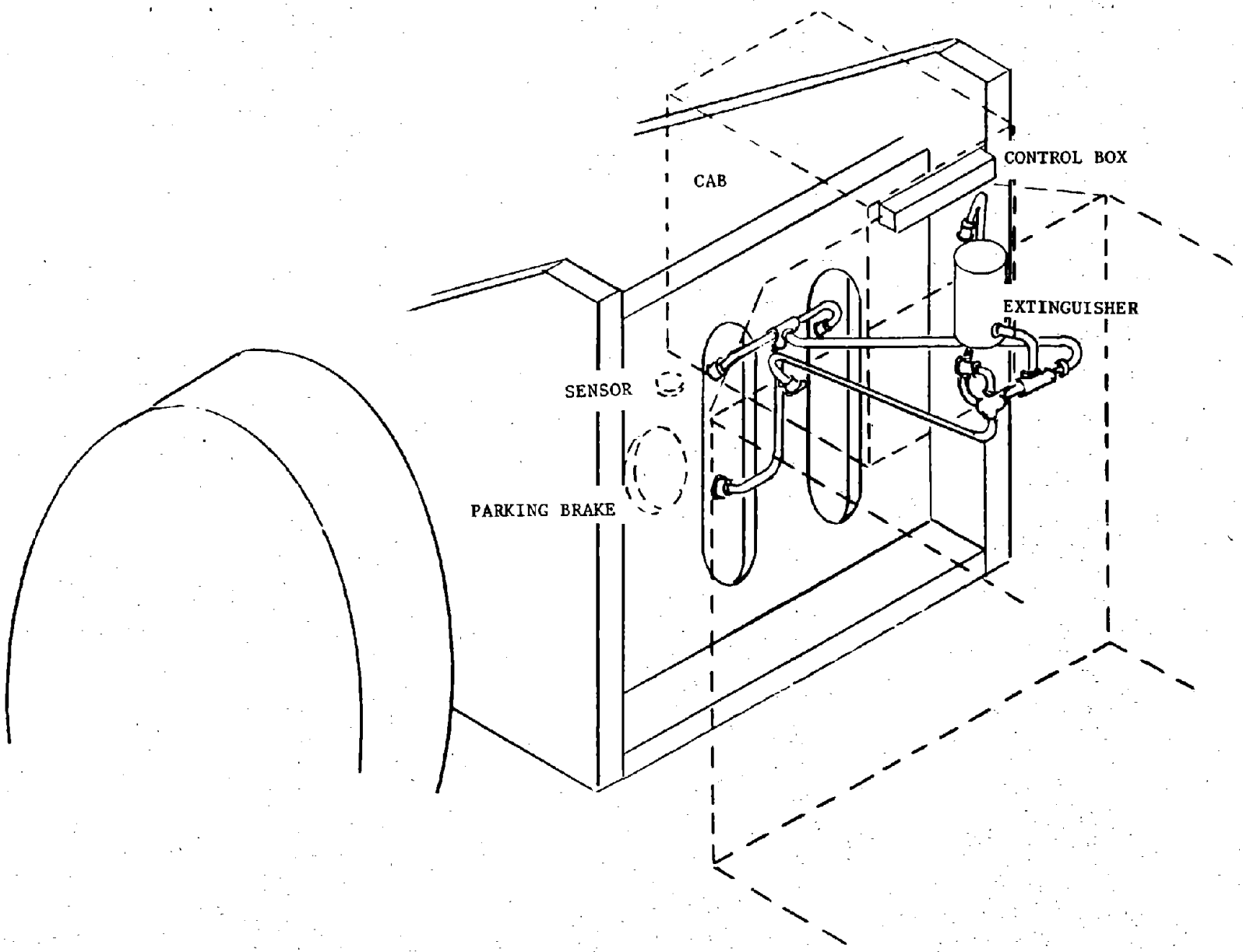


DETAIL "A"

675 ENGINE COMPARTMENT SYSTEM



675 TRANSMISSION COMPARTMENT
SYSTEM



DETAIL "C"

675 FRONT FRAME SYSTEM

DISTRIBUTION TEST ON "AFEX" FIRE SUPPRESSION SYSTEM

DATE CONDUCTED: June 2, 1976

OBSERVERS:

W. D. Lease	Lease "AFEX", Inc.
W. D. Lease, Jr.	Lease "AFEX", Inc.
G. F. Roll	Lease "AFEX", Inc.
R. Starr	Lease "AFEX", Inc.
P. H. Ellington	Southeastern Safety Appliances, Inc. (Ansul Distributor)

PROCEDURE:

A wood frame was constructed to simulate a tractor engine compartment and transmission compartment. Dimensions are given on Exhibit # 1, "Test Stand".

An "AFEX" Fire Suppression System was piped into the test stand which was typical of a single system installation as shown on the spec sheet. It was purposely unbalanced as much as possible to test and measure distribution of powder under the maximum conditions. The tubing path, size, and lengths are shown on Exhibit # 2, "System Dimensions".

Each of the five nozzles was covered with a paper vacuum cleaner bag and this bag in turn covered with a burlap bag. The paper bag served as a filter to capture the expelled powder and the burlap bag prevented the paper bag from bursting.

The extinguisher used was a typical model 30 shell and weighed 20# empty. It was filled with a total of 28# of Ansul plus-fifty B/C dry chemical.

TEST:

The first test showed some interesting data. Inadvertently the 1/2" x 1/2" x 3/4" TEE used at the forward end of the test stand "engine compartment" was not tightened on the 3/4" feed, or inlet, line. When the system was triggered, this fitting blew off and powder was expelled without restriction through this outlet as well as discharged through the upper rear engine compartment nozzle (#3) and the two transmission compartment nozzles (#4 and #5). At the end of the discharge the bags covering nozzles #3, #4, and #5 were removed and weighed. Surprisingly enough the bags all weighed almost identically - 4#4oz. or a discharge of 12#12oz. out of 26.6# total discharge. This indicates that in spite of the open-unrestricted 3/4" feed line to nozzles #1 and #2, and in spite of severe differences in distance from the extinguisher shell, equal discharge was experienced. Obviously the powder was splitting at the tees in the line so that practically equal amounts were flowing out each leg of the tee.

For the second test the 1/2" x 1/2" x 3/4" TEE was securely tightened and the filter bags replaced on nozzles #3, #4, and #5. Again 28# of dry chemical was put into the shell and the system made ready to fire. The system was triggered and completed discharge in 14 seconds. The filter bags were removed and weighed. Results are shown in Exhibit #3, "Test Results".

RESULTS:

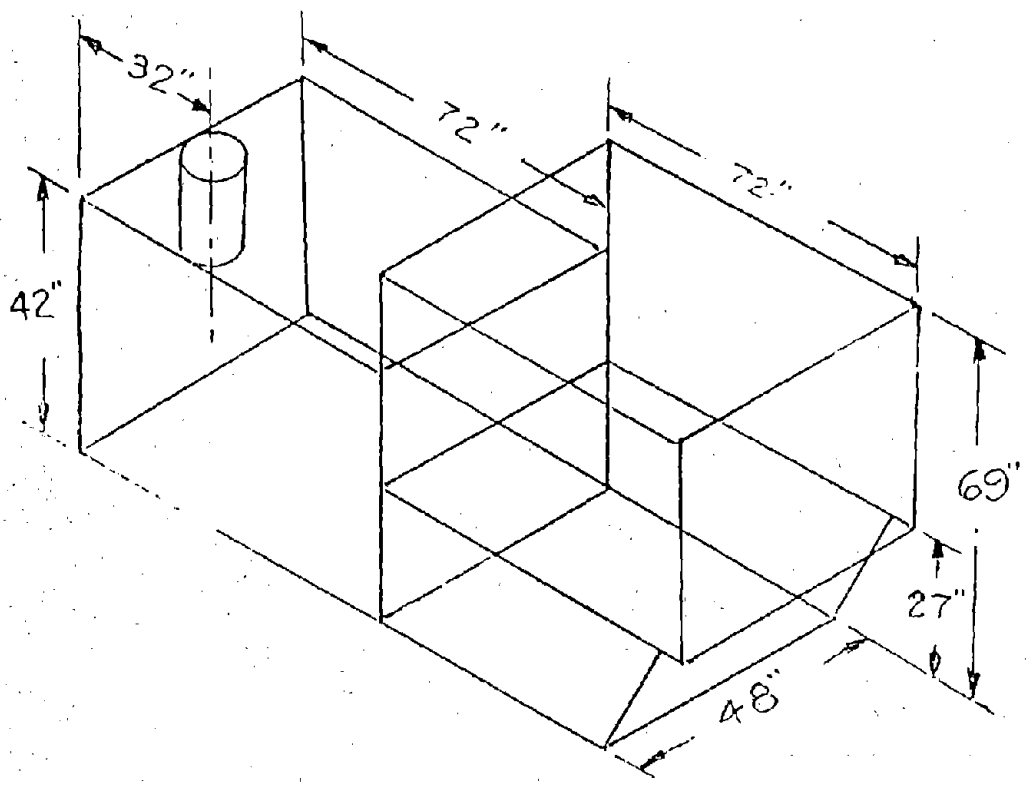
This second test proved that for all practical purposes discharge was equal at all five nozzles regardless of position or distance from the extinguisher. Weight varied by less than 1/2# from maximum to minimum individual nozzle discharge. Some minor losses were experienced at each nozzle by powder passing through the filter bag. Also a small amount remained in the extinguisher shell, approximately 8-9 oz. and the remainder, 3-4 oz. was blown out of the tubing network after discharge with a compressed air hose.

CONCLUSIONS:

The conclusions that can be made and are proven by actual test are:

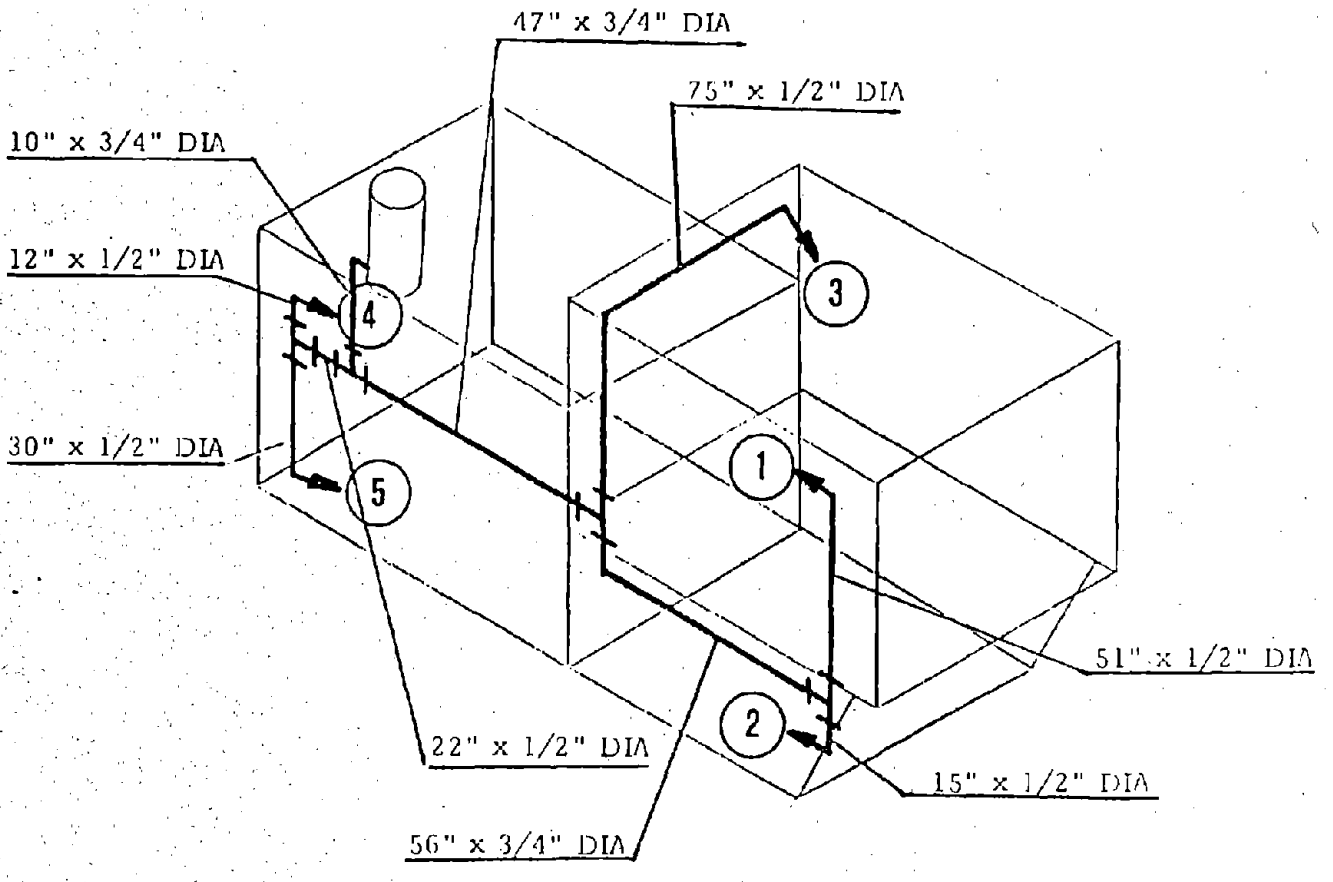
1. Regardless of configuration of piping, discharge is for all practical purposes equal at all five nozzles.
2. A break in one branch section of the tubing network does not seriously disable the system. The three effective nozzles still discharged over 75% of their normal discharge.
3. The use of steel tubing rather than schedule 40 steel pipe or flexible hose in no way affected distribution or total time of discharge.
4. The small amount of tubing used in the "AFEX" system allows great flexibility as to installation. A maximum of 20' of 1/2" steel tubing and a maximum of 10' of 3/4" steel tubing is supplied with each system.
5. Even though the nozzles were semi-restricted by the filter bags over them, the opening of the nozzle caps was not effected and sufficient pressure exists at the nozzle to effectively discharge under adverse conditions.
6. From the test results it can be assumed that the use of 1/2" and 3/4" tubing while having a smaller I.D. than schedule 40 pipe does not adversely effect the flow of powder. It is believed that because bends in the tubing have a much more generous radius than pipe ells the flow is less impeded and separation is less than with pipe fittings. Discharge of a 30# system using schedule 40 pipe or flexible hose is normally about 15-16 seconds as compared to 14 seconds discharge of the "AFEX" system.

EXHIBIT #.1



TEST STAND

EXHIBIT # 2



SYSTEM DIMENSIONS

EXHIBIT # 3

TEST RESULTS

	Test Number		1	2
1.	Discharge Time		13 Seconds	14 Seconds
2.	Net Weight Powder Discharged At Nozzle (Pounds)	#1	N.A.	5#-7oz.
		#2	N.A.	5#-1oz.
		#3	4#-4oz.	5#-8oz.
		#4	4#-4oz.	5#-7oz.
		#5	4#-4oz.	5#-2oz.
3.	Total Nozzle Discharge		12#-12oz.	26#-9oz.
4.	Extinguisher Shell, Empty		20#	20#
5.	Extinguisher Shell, Full		48#	48#
6.	Per cent Total Discharge		95.1%	94.4%
7.	Per cent Discharge, Nozzle	#1	N.A.	20.48%
		#2	N.A.	19.05%
		#3	15.97%	20.70%
		#4	15.97%	20.48%
		#5	15.97%	19.29%

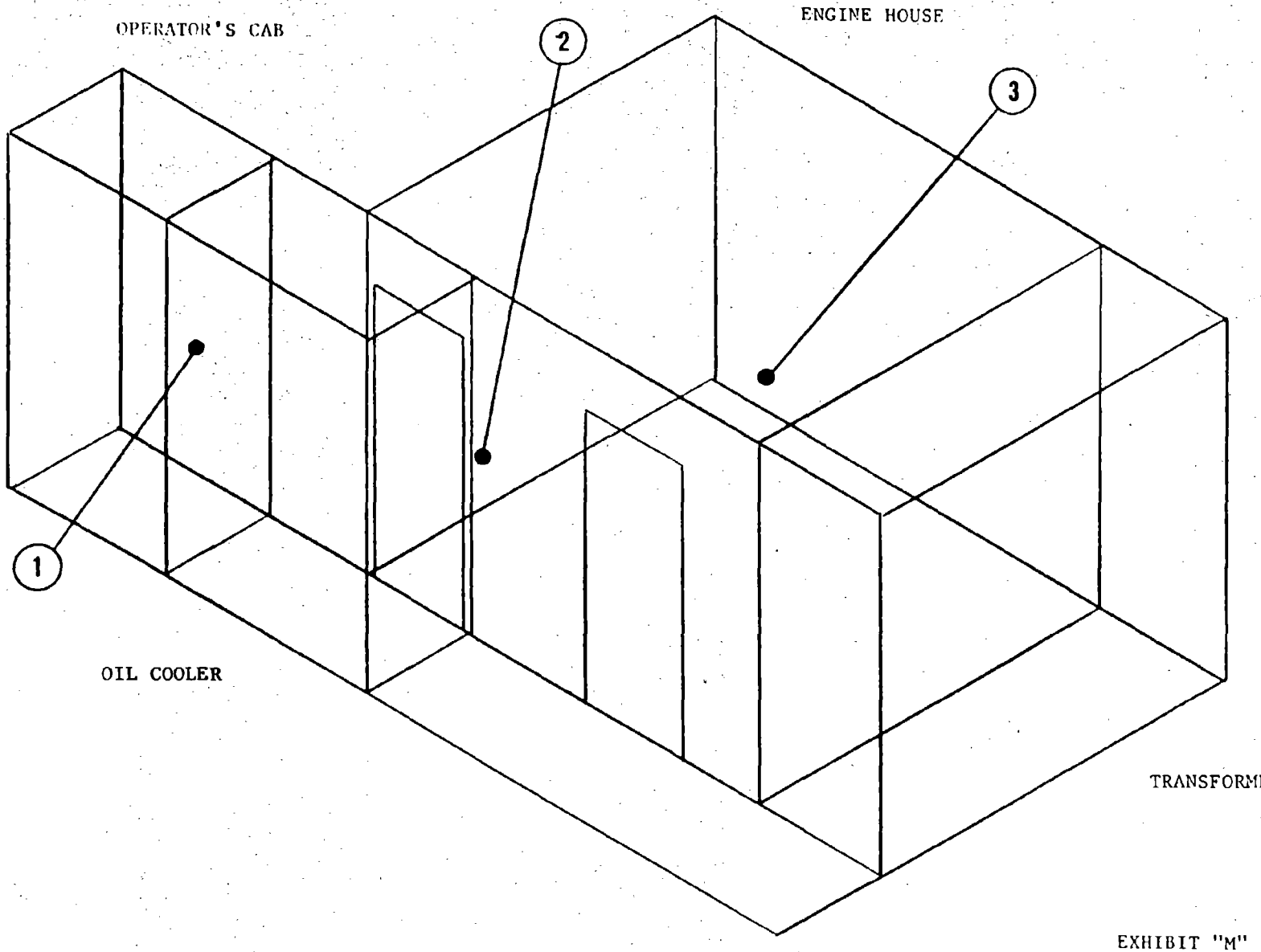


EXHIBIT "M"
61R DRILL
HALON MONITORS

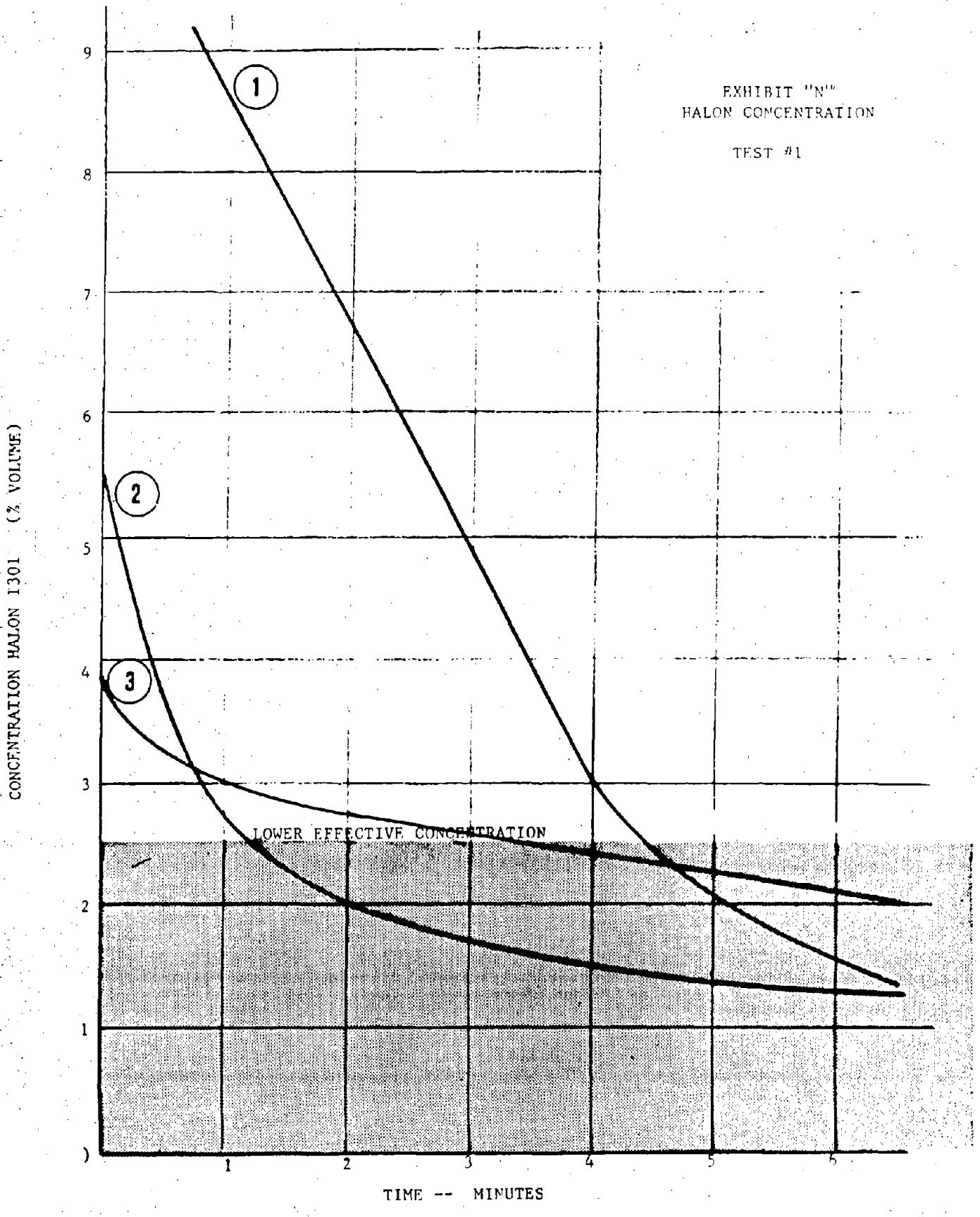


EXHIBIT "N"
HALON CONCENTRATION
TEST #1
CONCENTRATION HALON 1301 (% VOLUME)
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
1
2
3
LOWER EFFECTIVE CONCENTRATION
TIME -- MINUTES

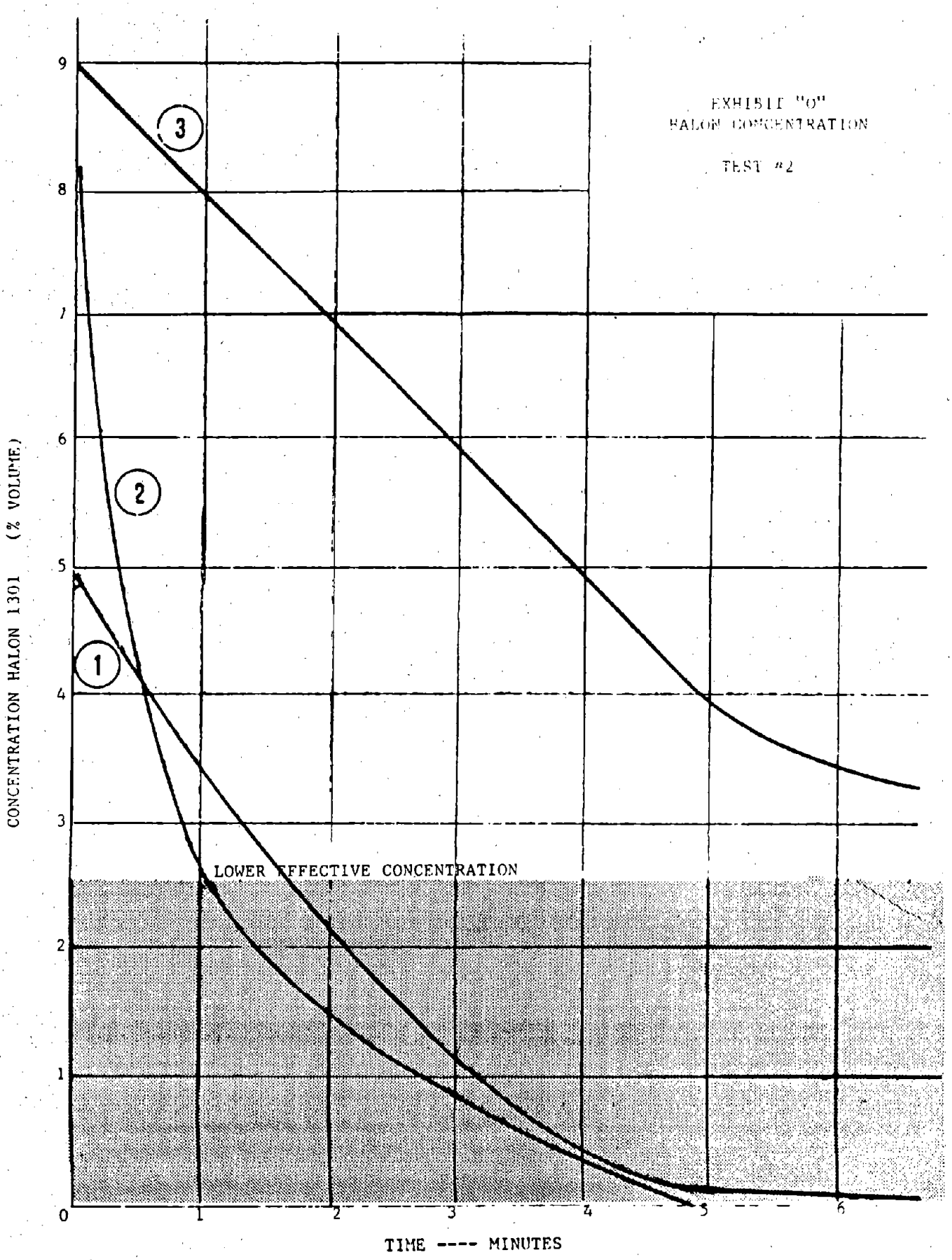


EXHIBIT "O"
HALON CONCENTRATION
TEST #2
CONCENTRATION HALON 1301 (% VOLUME)
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
TIME ---- MINUTES
LOWER EFFECTIVE CONCENTRATION
1
2
3

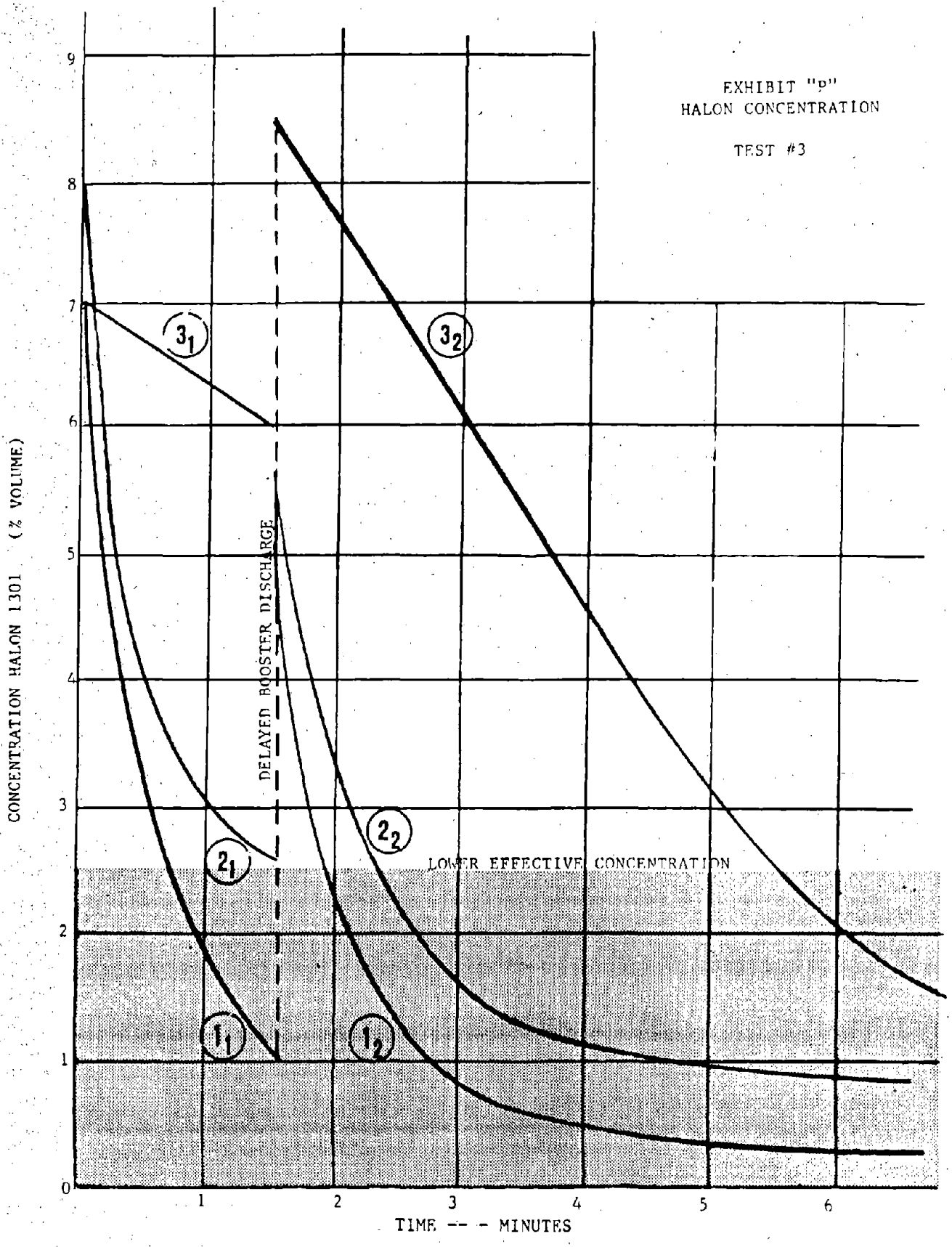
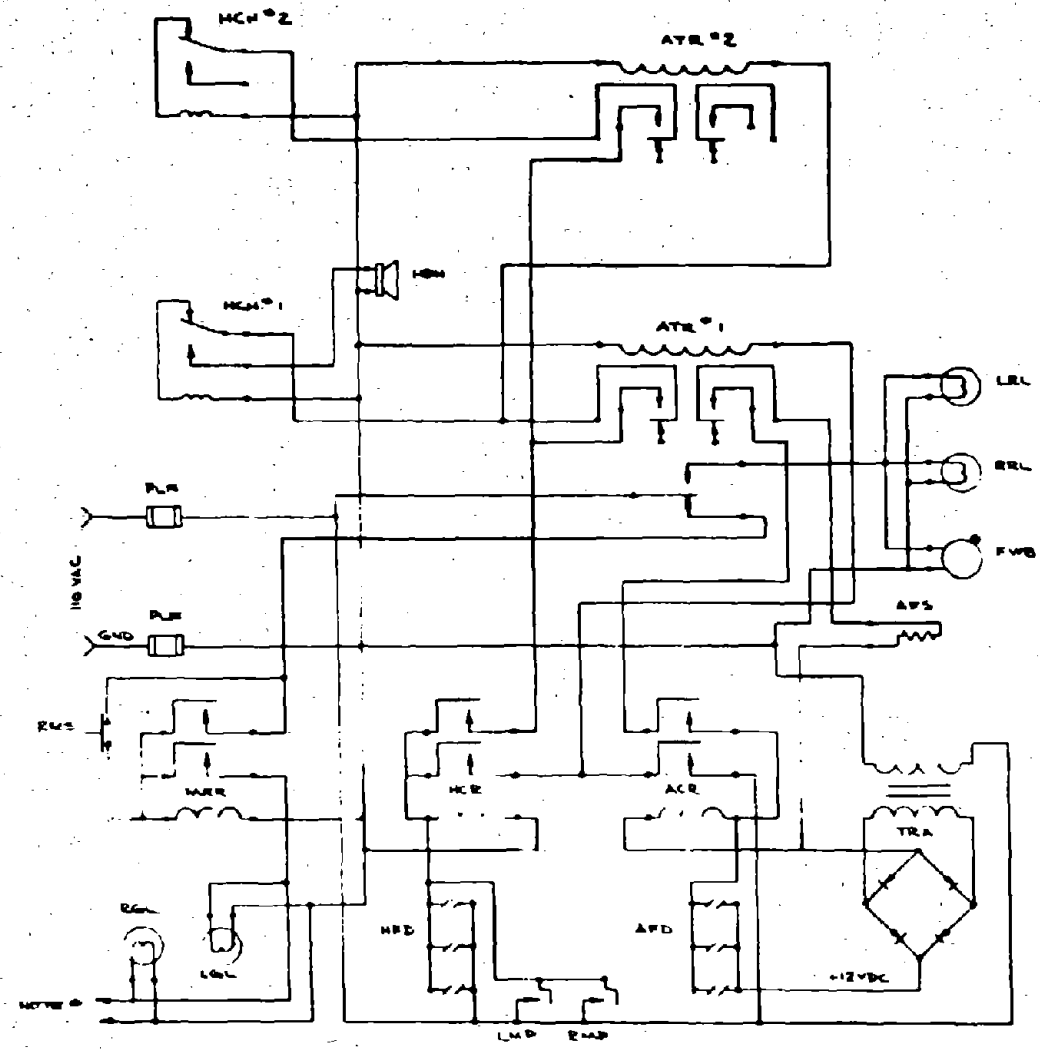


EXHIBIT "P"
HALON CONCENTRATION
TEST #3
CONCENTRATION HALON 1301 (% VOLUME)
TIME -- - MINUTES
DELAYED BOOSTER DISCHARGE
LOWER EFFECTIVE CONCENTRATION
3_1
3_2
2_1
2_2
1_1
1_2
0
1
2
3
4
5
6
7
8
9



DES SYM	DESCRIPTION
ACR	APEX CONTROL RELAY
APD	APEX FIRE DETECTORS
APS	APEX FIRING SQUIB
ATR	ADJUSTABLE TIMING RELAY
FWB	FIRE WARNING BELL
HCH	HALON CONTROL HEAD
HCR	HALON CONTROL RELAY
HRN	HALON DISCHARGE HORN
HFD	HALON FIRE DETECTORS
LGL	LOCAL GREEN LIGHT
LMP	LOCAL MANUAL PULL
LRL	LOCAL RED LIGHT
MRR	MANUAL RESET RELAY
PLF	POWER LINE FUSE
RGL	REMOTE GREEN LIGHT
RMP	REMOTE MANUAL PULL
RRL	REMOTE RED LIGHT
RRS	RELAY RESET SWITCH
TRA	TRANSFORMER RECTIFIER

NOTE ✱	CONNECT IN PARALLEL TO RELAYS ON THESE CIRCUITS
	OPERATOR'S CAB A/C MOTOR
FPF1	FAN PUMP FUSE 1
FPF2	FAN PUMP FUSE 2
M&F	MAIN SET MOTOR FUSE
OCM	OIL COOLER MOTOR
HFF	HYDRAULIC FAN FUSE

	Lease AFEX, Inc.	
	DWG 61-E	NONE — WDL JR.
	APEX-HALON FIRE CONTROL PANEL	
	21 JUL 78	USBM CONTRACT H0262009

Automatic Halon/Dry Chemical Fire Protection System for Large Blasthole Drills

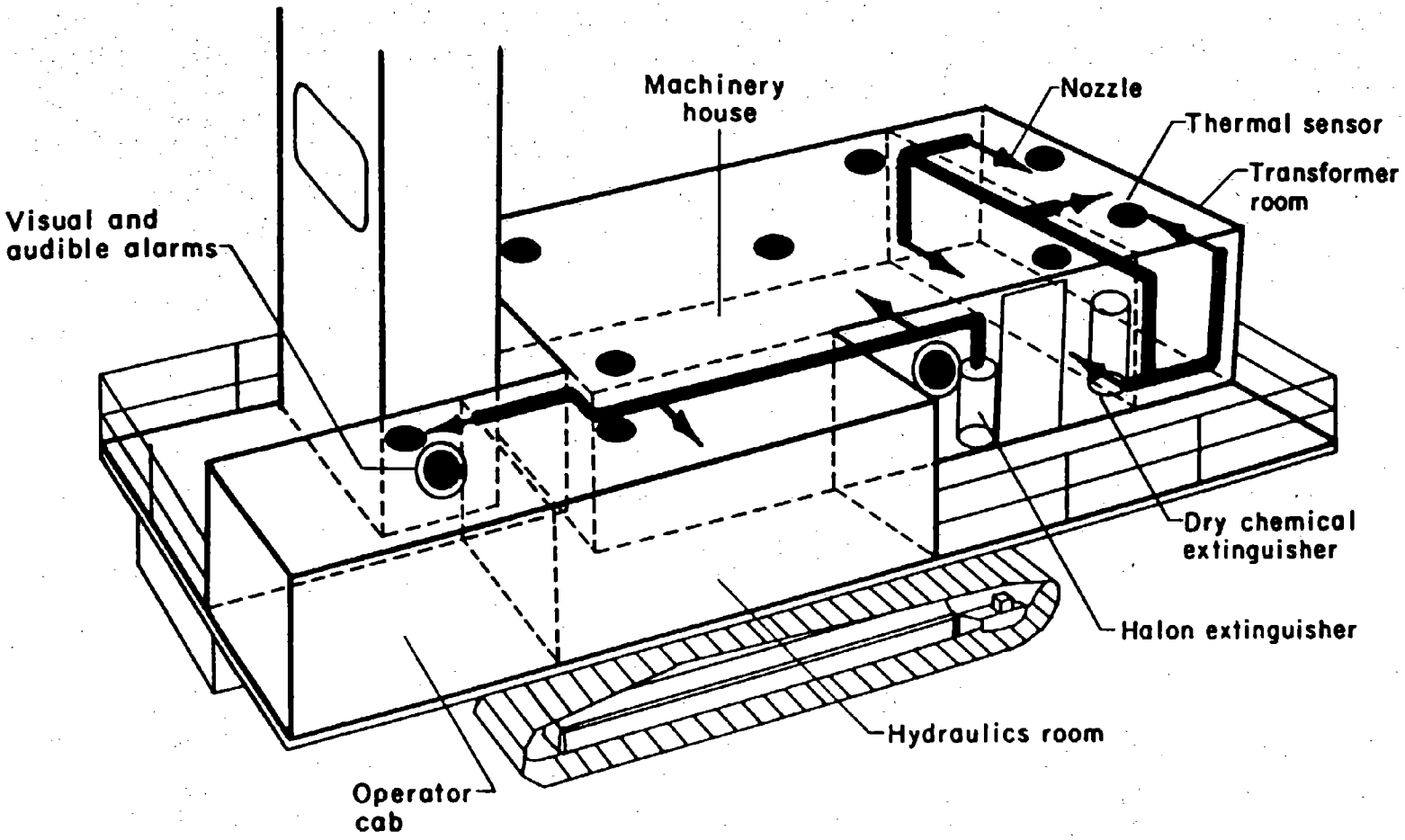


FIGURE "R"

HALON 1301 CONTROL PANEL-(RIGHT SIDE)
NOTE PRESSURIZING FAN INLET AT LEFT SIDE.

FIGURE 5

HALON 1301 CONTROL PANEL; NOTE MANUAL PULL STATION, STATUS LIGHTS AND RESET SWITCH.

FIGURE "T"

"AFEX" DRY CHEMICAL DISCHARGE IN TRANSFORMER AREA
(TIME = 5 SECONDS)

FIGURE "U"

Automatic Fire Protection System for Large Front End Loaders

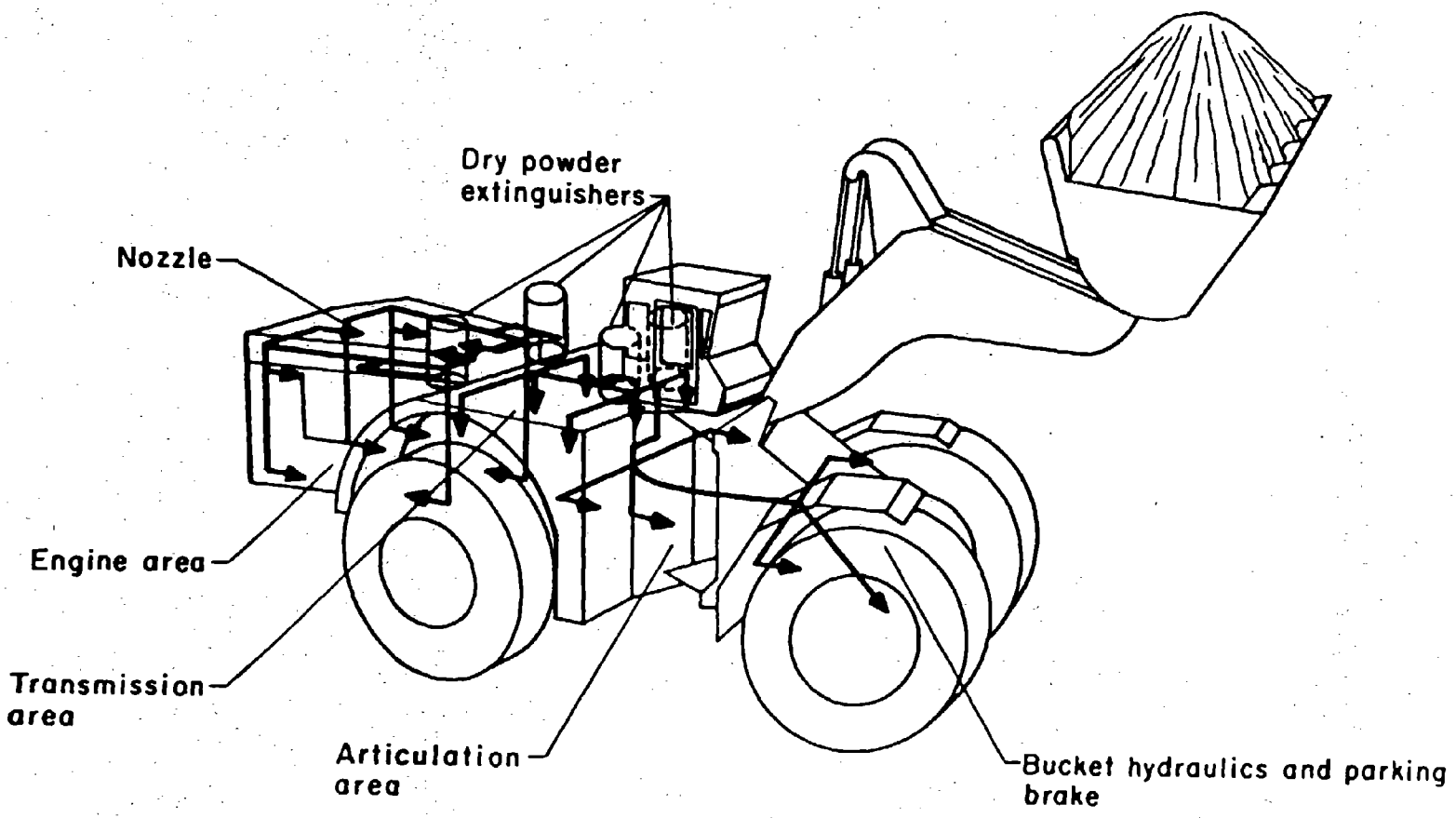
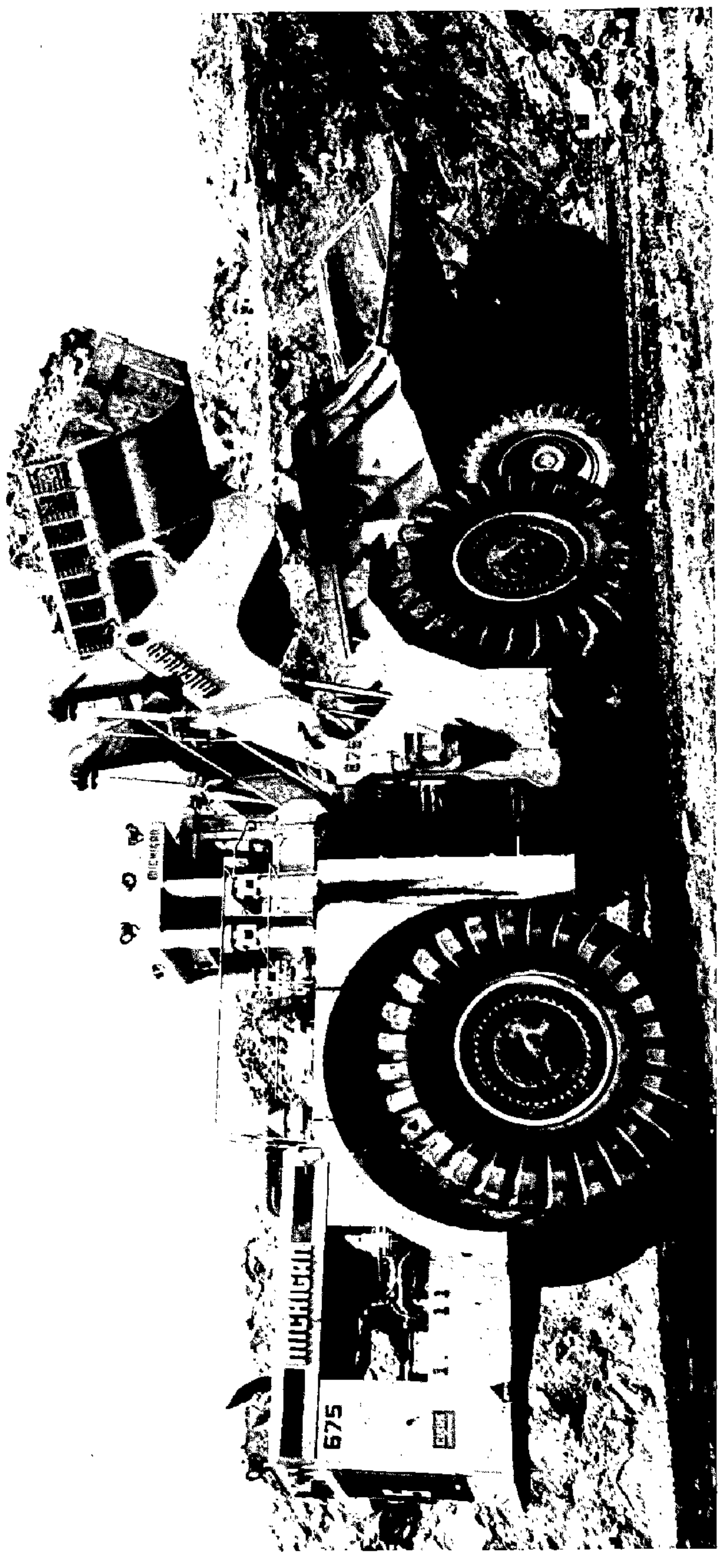


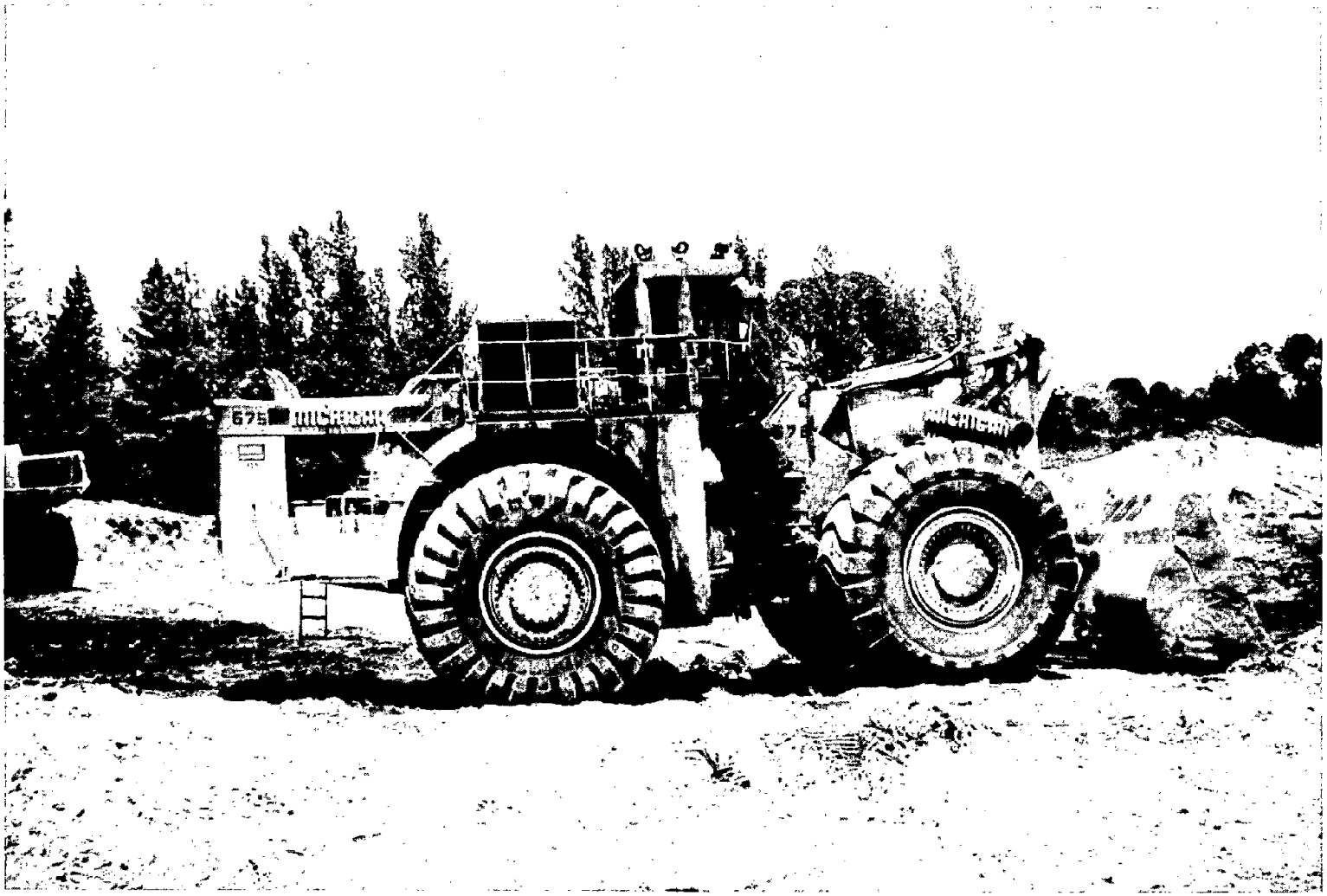
FIGURE "V"



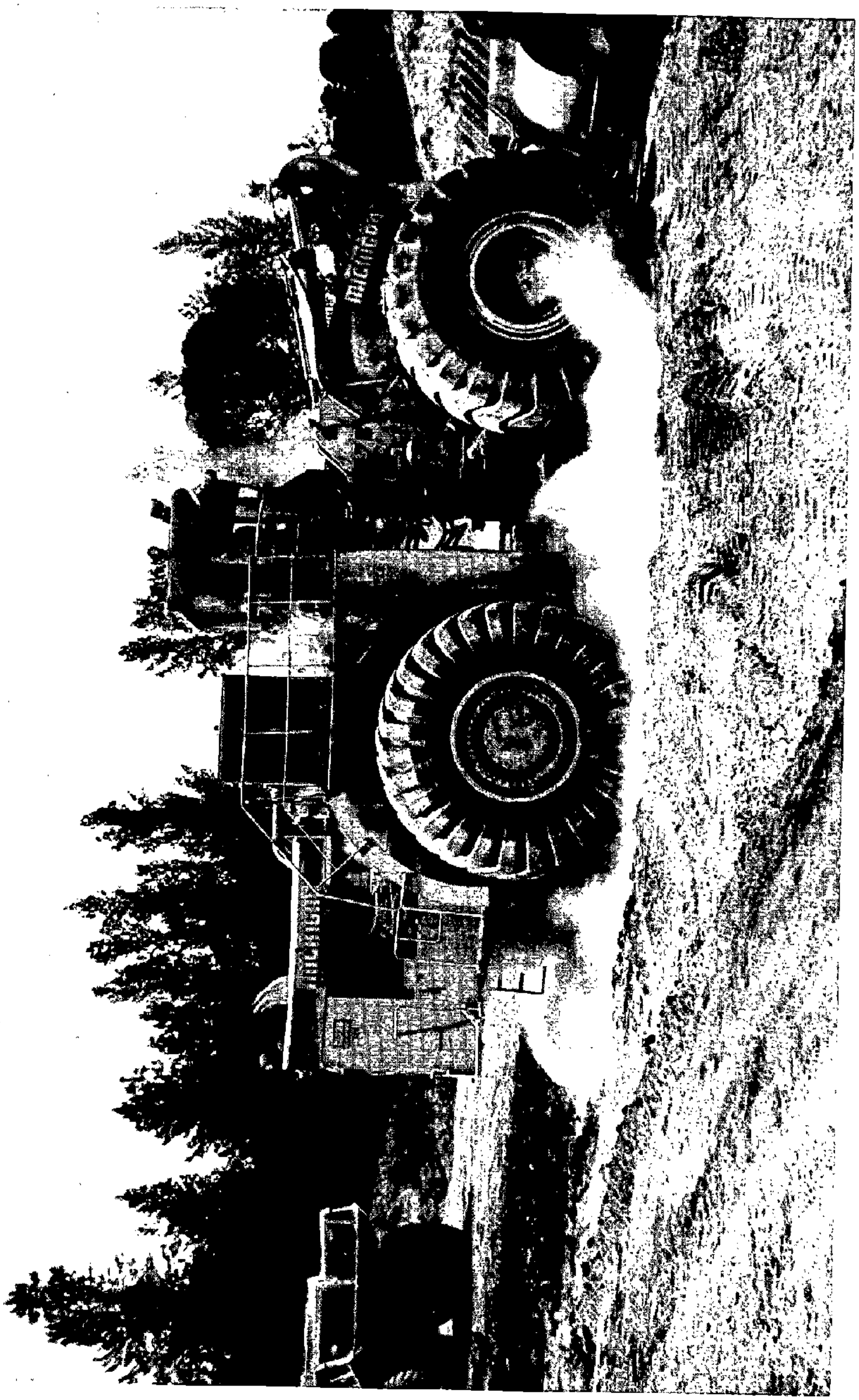
THE CLARK 675 LOADER

FIGURE "W"

FIGURE "X"

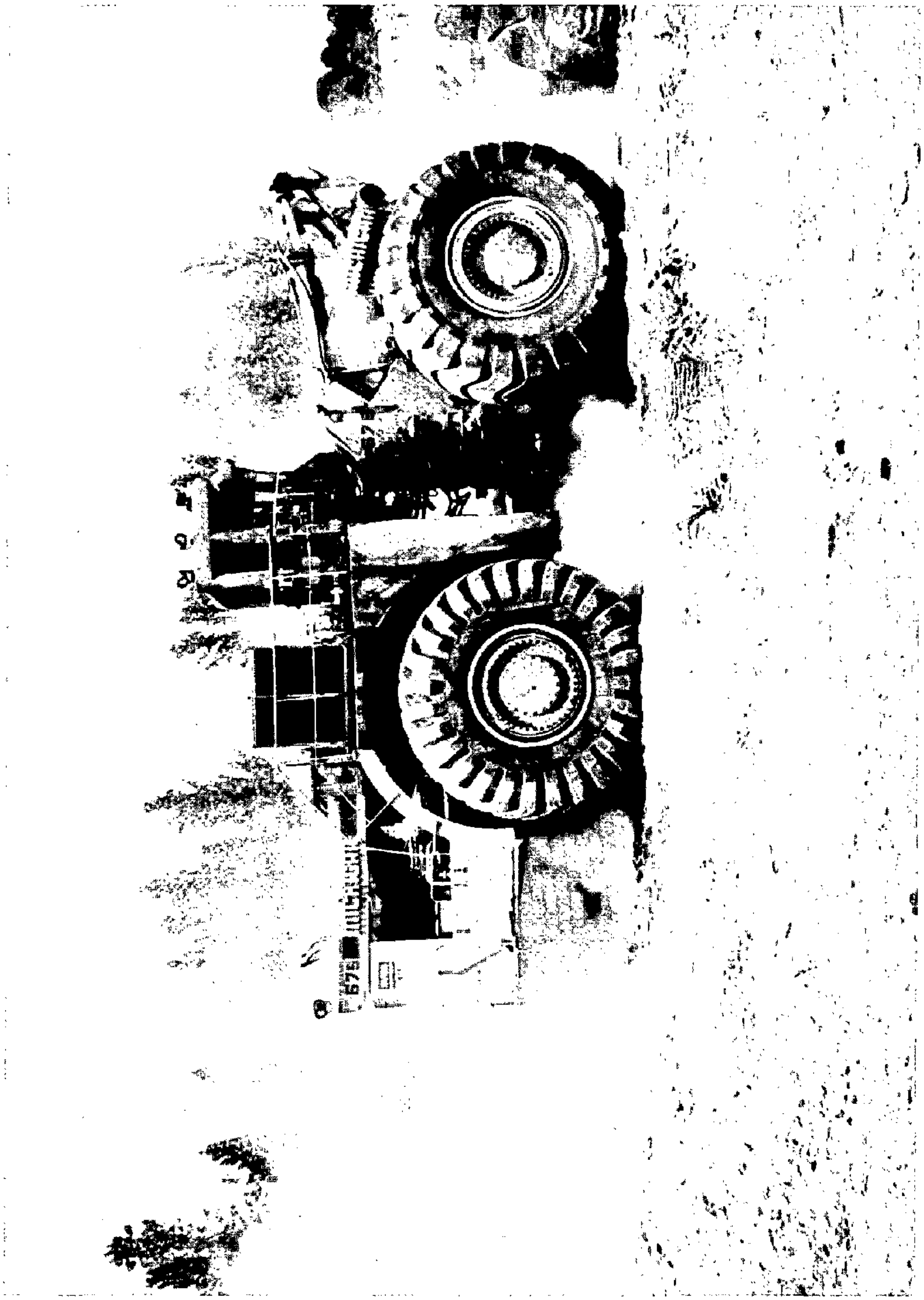


"AFEX" DRY CHEMICAL DISCHARGE
(TIME = 5 SECONDS)



"AFEX" DISCHARGE CONTINUED
(TIME = 10 SECONDS)

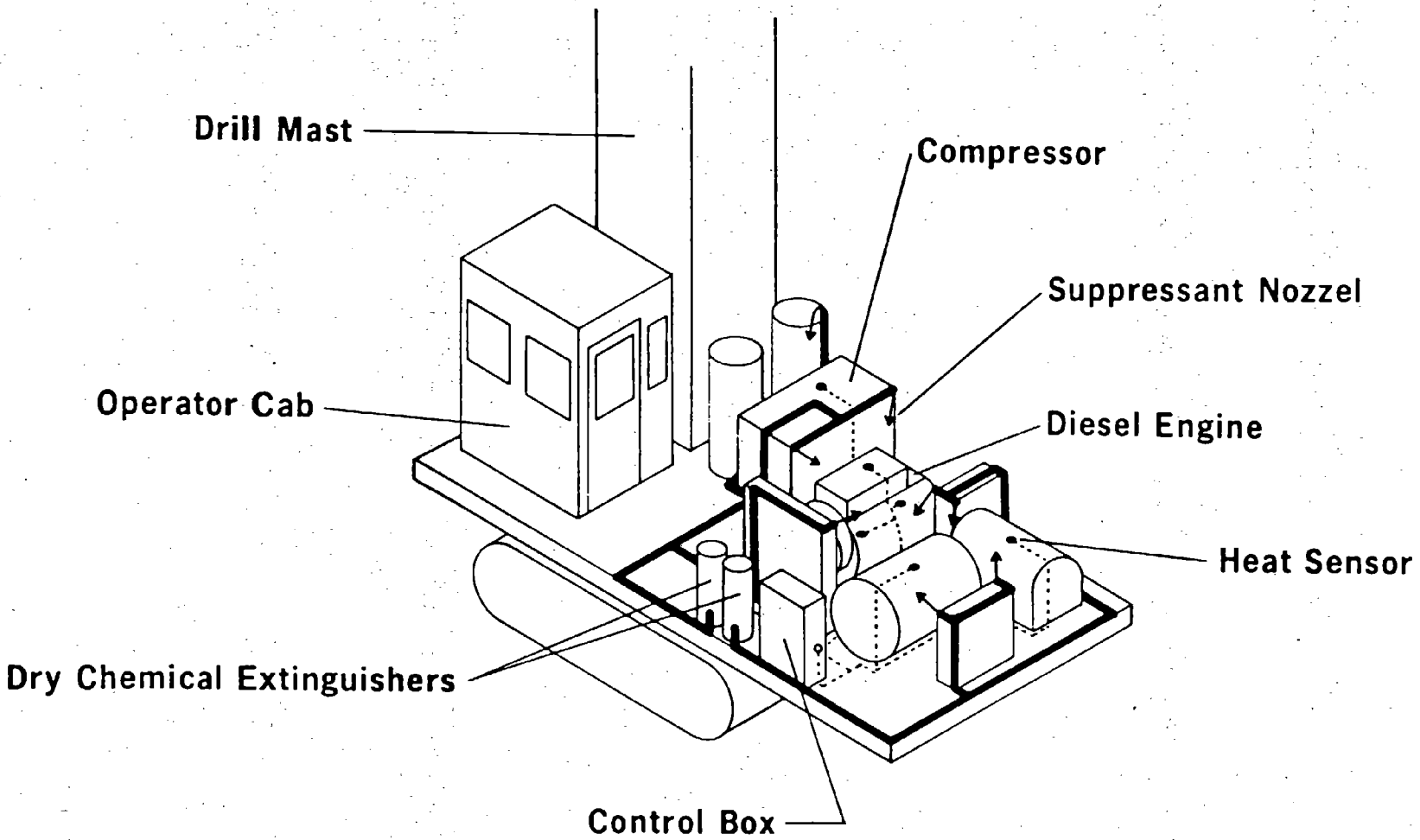
FIGURE "X2"



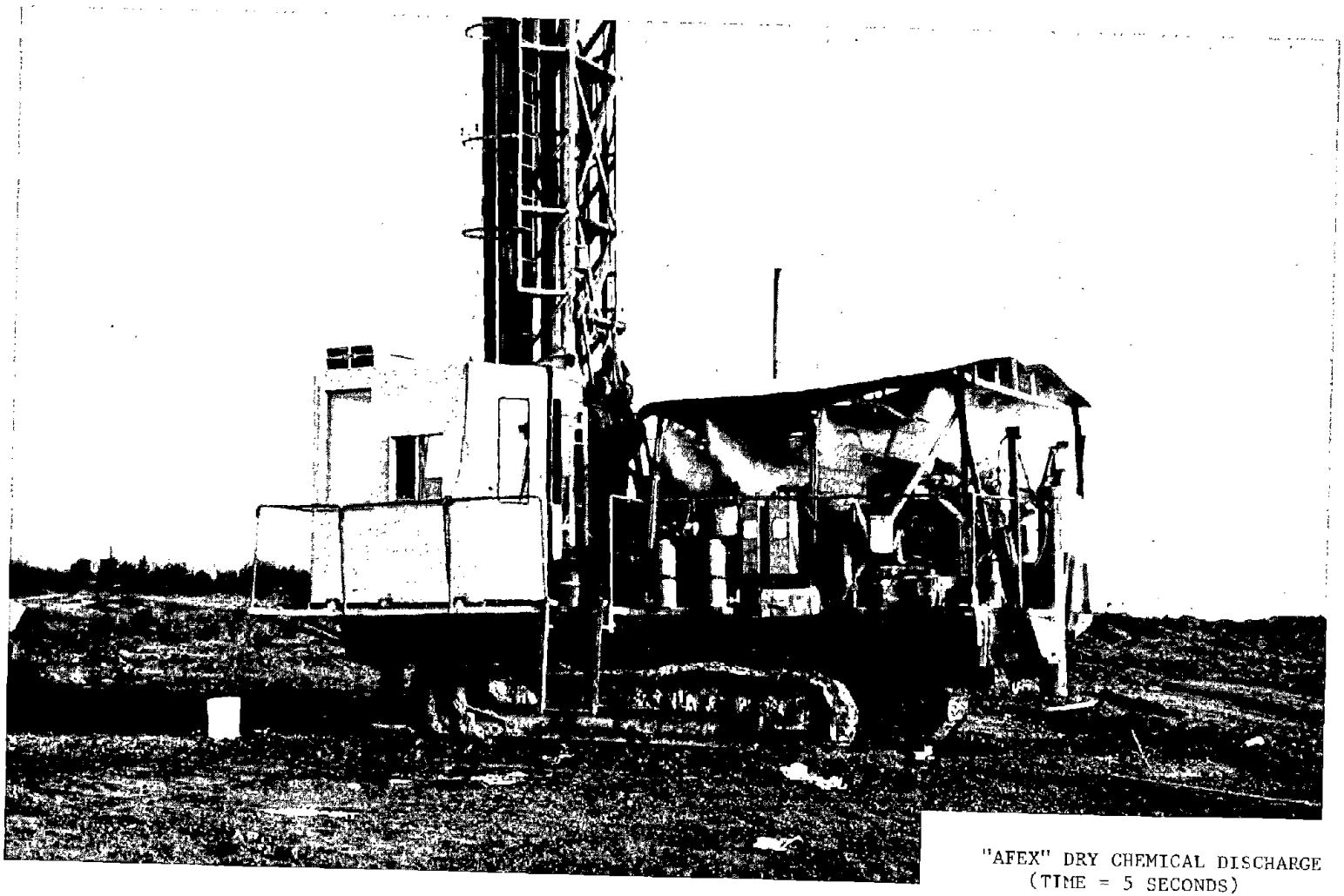
"AFEX" DISCHARGE CONTINUED
(TIME = 15 SECONDS)

FIGURE "X3"

FIGURE "Y"

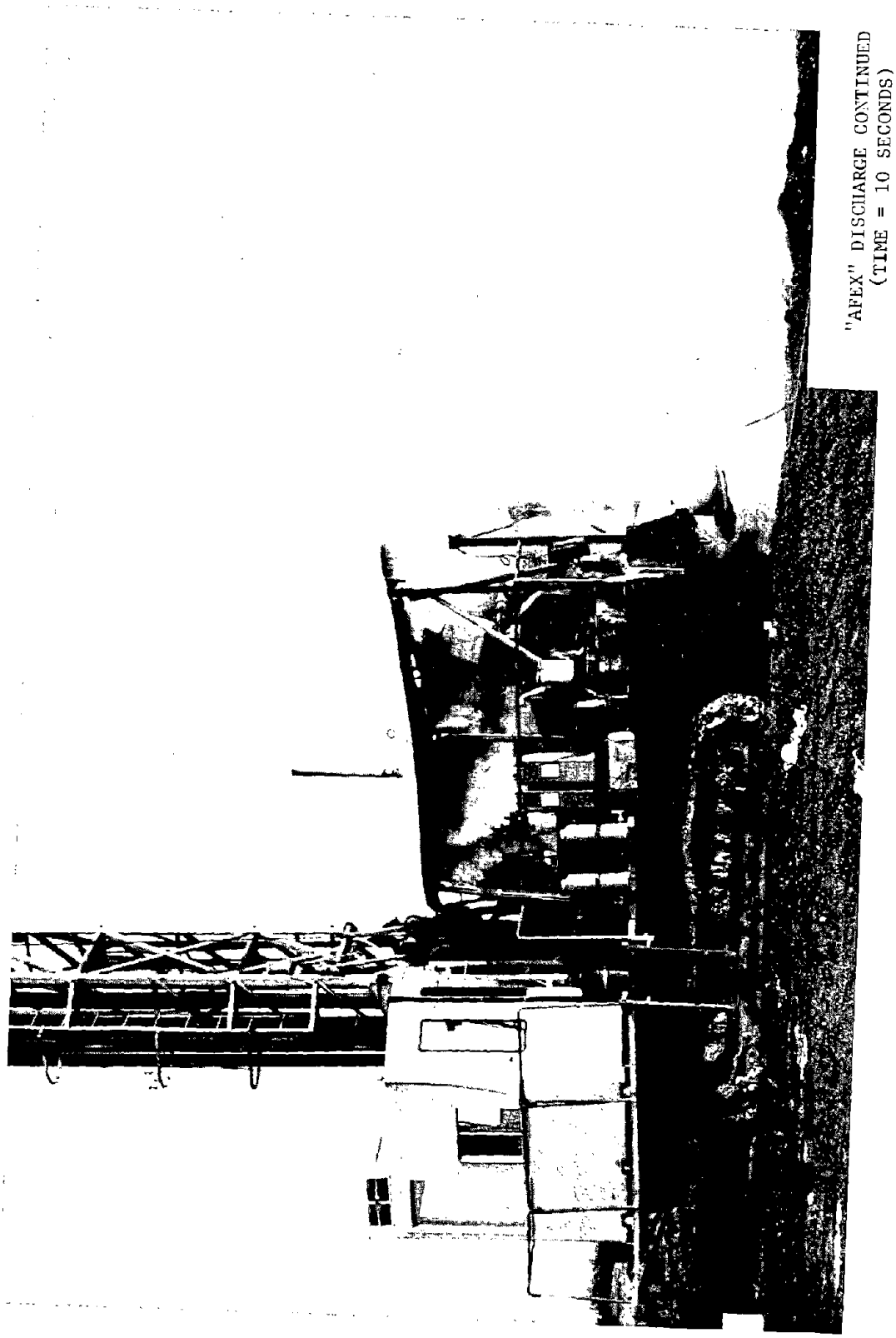


AUTOMATIC FIRE PROTECTION FOR SMALL MINING DRILLS



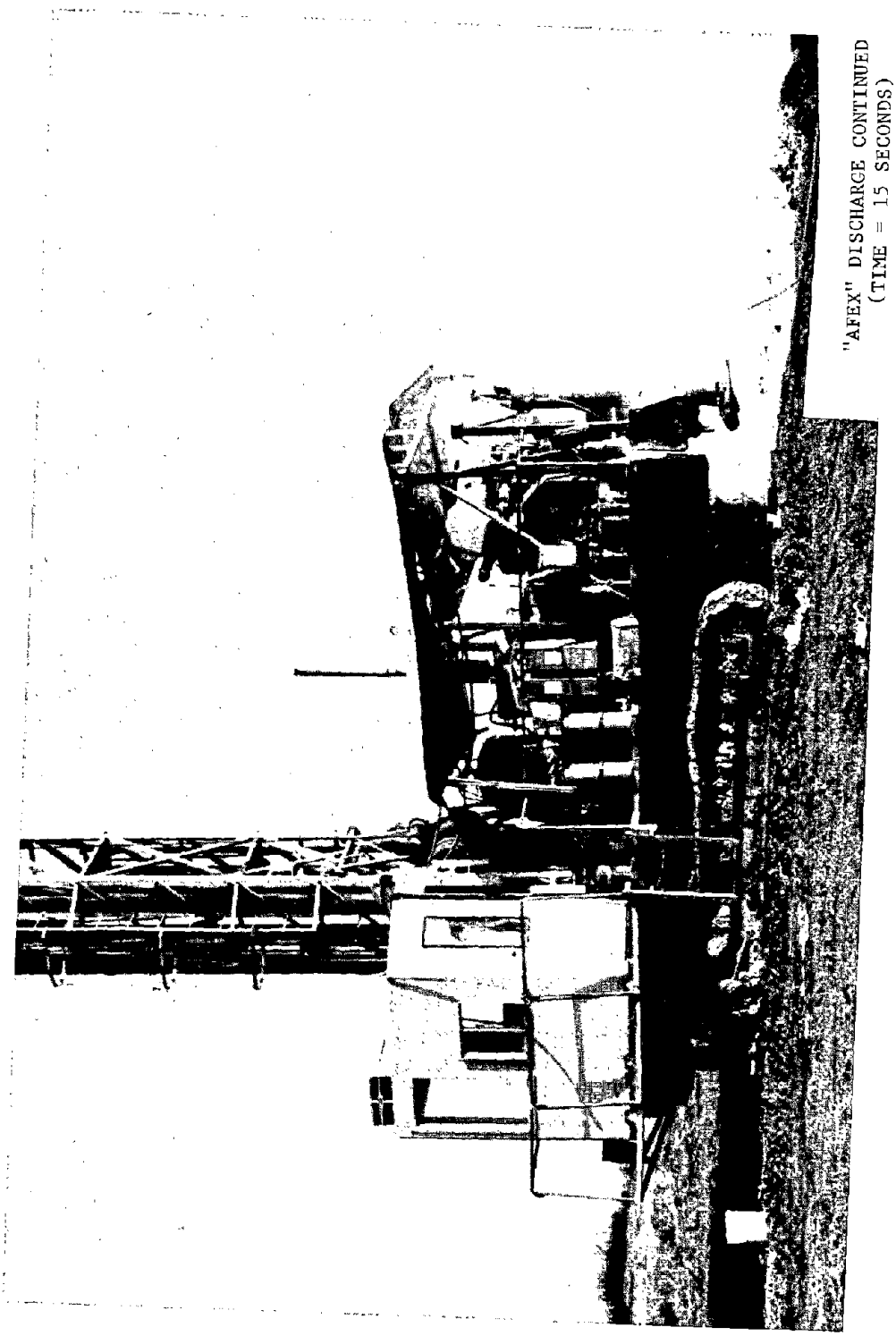
"AFEX" DRY CHEMICAL DISCHARGE
(TIME = 5 SECONDS)

FIGURE "Z"



"AFEX" DISCHARGE CONTINUED
(TIME = 10 SECONDS)

FIGURE "Z2"



"AFEX" DISCHARGE CONTINUED
(TIME = 15 SECONDS)

FIGURE "Z3"