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By
Gary Anguiano

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RAPID PIPELINE REPAIR TECHNOLOGY FOR WAR DAMAGE RECOVERY

ABSTRACT This report documents the development of three experimental pipeline couplers for rapid repair of fuel lines damaged in an attack. The experimental couplers are: (1) the Cold Forge coupler, (2) the Internal Coupler, and (3) the Inflatable Seal Coupler. The focus of the evaluation was to determine the feasibility of rapidly repairing bomb-damaged fuel lines with each coupler, particularly underground pipelines made of carbon steel. Evaluating the feasibility of repair with each coupler was based on such aspects as installation speed and effectiveness.

The test results confirmed that each coupler could be used during base recovery operations to rapidly and effectively repair a fuel pipeline that may be out-of-round or highly misaligned. Recommend that each experimental coupler be taken into advanced development for extensive testing and field evaluation.

NAVAL CIVIL ENGINEEING LABORATORY PORT HUENEME CALIFORNIA 93043-4328

METRIC CONVERSION FACTORS

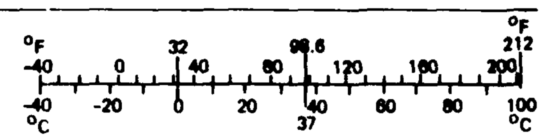
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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13. ABSTRACT (Maximum 200 words)

This report documents the development of three experimental pipeline couplers for rapid repair of fuel lines damaged in an attack. The experimental couplers are: (1) the Cold Forge coupler, (2) the Internal Coupler, and (3) the Inflatable Seal Coupler. The focus of the evaluation was to determine the feasibility of rapidly repairing bomb-damaged fuel lines with each coupler, particularly underground pipelines made of carbon steel. Evaluating the feasibility of repair with each coupler was based on such aspects as installation speed and effectiveness.

The test results confirmed that each coupler could be used during base recovery operations to rapidly and effectively repair a fuel pipeline that may be out-of-round or highly misaligned. Recommend that each experimental coupler be taken into advanced development for extensive testing and field evaluation.

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1.0 INTRODUCTION

This report documents the exploratory development of three experimental pipeline couplers for rapidly repairing fuel lines damaged by an enemy attack. The couplers are: (1) the Cold Forge Coupler, (2) the Internal Coupler, and (3) the Inflatable Seal Coupler. The focus of the evaluation was to determine the feasibility of repairing bomb-damaged fuel lines with each coupler, particularly underground pipeline made of carbon steel. The feasibility of repair with each coupler was determined based on such aspects as installation speed and effectiveness for holding pressure (after installation).

2.0 BACKGROUND

2.1 Operational Problem

In 1985, the United States Air Force (USAF) conducted a major exercise, Salty Demo, at a North Atlantic Treaty Organization (NATO) airbase. The purpose of the exercise was to evaluate USAF their capability to recover the function of facilities damaged by an air strike. The exercise pointed out deficiencies in fuel pipeline repair. These deficiencies seriously affected the ability of the Air Force to complete their primary mission, "sortie generation." It can be shown that the effect of a similar air strike on a forward Naval Base could also significantly impact Navy aircraft operations.

2.2 Repair Scenario

Repairing fuel pipelines at a Navy Base following an enemy attack can be extremely difficult. The difficulties include unexploded ordnance and contamination from chemical weapons near the repair site. Loss of key assets, such as roadways and fuel farm personnel, could also hamper repair. Competing base recovery priorities, such as repairing bomb-damaged runways first, may reduce/eliminate the availability of essential pipeline repair equipment. Fuel line repair, particularly in a bomb crater, is extremely hazardous. The disruption of other utility lines (water, electrical, and communications) further hinders base recovery efforts.

2.3 Base Recovery Tasks

Development of the three couplers was conducted under the Office of Naval Technology Exploratory Development Task C3: Base Recovery. The task consisted of four milestones: (1) Repair Technologies, (2) Knowledge-Based System Technology, (3) Construction Management, and (4) Computer Simulation. This report only addresses Milestone 1, Repair Technologies. It is intended, however, that all milestones be integrated into a system that provides Navy Bases with comprehensive recovery capability. Appendixes A and B contain Technical Memoranda for Milestones 2 and 3 of this task. Milestone 4 was cancelled due to funding cuts.

3.0 NAVY BASE FUEL SYSTEMS

3.1 Types of Fuel

Most Naval fuel farms store and dispense several types of fuels. The commonly used fuels in Naval aircraft are JP-5 and JP-8. Some bases have multiple pipelines capable of dispensing other types of fuel, including JP-4 (for Air Force aircraft), AVGAS, MOGAS, and Diesel. In terms of repair safety, the flashpoint of fuel is very important. JP-4 has a flashpoint of -20°F, while JP-5 has a flashpoint of 140°F.

3.2 Navy Fuel Pipelines

Fuel pipelines found at most advanced Naval Bases are made either of carbon steel, stainless steel, or aluminum. Most of the older bases use carbon steel pipeline. These carbon steel pipelines are usually coated to prevent corrosion. The coating is made of one or more of the following materials: polyethylene, polypropylene, fusion bonded epoxy, or coal tar. Stainless steel pipelines are found in some of the more recently constructed fuel installations. Aluminum pipeline is often used downstream of fuel filters, because it is nonferrous. Neither the stainless steel nor the aluminum pipe is coated.

3.3 Pipe Sizes

Navy fuel pipelines range from 4 to 28 inches in diameter. In general, the pipelines used for refueling aircraft are less than 14 inches in diameter. Advanced bases with extensive bulk storage facilities use larger diameter pipe to achieve higher volumetric flow. For the purpose of this evaluation, it was determined that NCEL would focus on pipelines under 12 inches in diameter.

3.4 Distribution Pressures and Flows

Fuel line flow rates are typically under 1,200 gallons per minute (gpm). Operating pressures are typically 150 pounds per square inch (psi). Some bases have distribution systems that can refuel multiple aircraft while maintaining pressures of 45-55 psi at the aircraft fuel tank inlets. Typical flow rates into aircraft range from 250 to 600 gpm, depending on the aircraft type.

3.5 Pressure Transients

Naval fuel distribution systems are designed to tolerate induced pressure transients. Reference 1 states that the designs for new fuel facilities should provide for pressure transients induced by emergency valve closure and pump shutoff. Total pressure, which includes pressure transients, is not expected to exceed 275 psi.

4.0 CHARACTERISTICS OF STEEL PIPELINE DAMAGE

The USAF has conducted extensive testing to determine the survivability and damage characteristics of underground steel pipeline subjected to bomb blast. Recent testings were conducted at Meppen, Germany and at Kirtland AFB, New Mexico. The damage from bomb blast included cracking, pipe distortion, and complete pipeline severance. Testing showed that a pipeline near the detonation point (within 3 feet) would be blasted severely out of alignment. Testing also showed that the cross section of the pipe several feet away from the detonation point would be distorted (oval shaped). Extensive excavation was required to reach pipeline that was both aligned and in-round.

5.0 PIPELINE REPAIR

5.1 Conventional Repair Process

Conventional techniques for repairing damaged fuel lines are based on welding or coupler technologies. Repair using welding technology requires trained specialists who are familiar with working in flammable environments. Since welding introduces the potential for fuel vapor ignition at the repair site, measures must be taken to purge the line. To repair out-of-round and misaligned pipe would require extensive excavation to reach undeformed pipe ends. Welding a 6-inch-diameter carbon steel replacement pipe would require transporting and handling a pipe weighing several hundred pounds (a 20-foot section of 6-inch-diameter schedule 40 carbon steel pipe weighs approximately 400 pounds). Since the technology would require the base to have dedicated pipeline welders (specialists) with expensive equipment for vapor purging, excavation, and material handling (pipe), welding was not considered feasible for base recovery scenarios.

Pipeline repair using commercially available couplers can be as difficult as using welding technology. Like welding, couplers require in-round and aligned (within 2 degrees) pipe ends. Additionally, a heavy replacement section as well as excavation and material handling equipment are also required for the coupler repair method. Therefore, it was determined that using commercially available coupler techniques would not be feasible in rapid repair.

6.0 PIPELINE REPAIR REQUIREMENTS

The repair requirements documented below were formulated by the author based on discussions with personnel from the Naval Facilities Engineering Command, the United States Air Force Civil Engineering Support Center, NATO Fuel Installation Working Group, and commercial pipeline repair experts. A decision point review was conducted in 1990 at the Naval Civil Engineering Laboratory to evaluate the direction and objectives of the base recovery program. In attendance were various users including personnel from the Naval Petroleum office. It was determined at the decision point review that the overall direction and established objectives were appropriate.

6.1 Transition Sponsor's Objectives

The Naval Facilities Engineering Command (NAVFACENGCOM) is the proponent for a rapid pipeline repair kit. It has provided NCEL with guidelines toward developing new pipeline repair concepts for the Naval Construction Force (NCF). Those guidelines focus on repair concepts that are effective, transportable, affordable, and compatible with existing Naval distribution systems. Furthermore, eliminating or minimizing the need for dedicated support equipment, such as trailers, prime movers, and backhoes was also a major concern.

6.2 Lightweight

Developing pipe repair couplers that join lightweight replacement sections to the hardwall steel pipe is a key requirement in expedient pipeline repair. Layflat hoseline which is extremely light (a 6-inch-diameter layflat hoseline weighs only 1.3 lbs/ft), can significantly benefit the repair process because it can be easily transported to the repair site and installed by one person. Thus, the need for a large repair crew, dedicated heavy material handling equipment, and other logistic support equipment would be eliminated.

6.3 Flexibility

Repair couplers that allow maximum flexibility in repairing fuel distribution systems are highly appropriate in base recovery. The many variables in base recovery make the typical situation difficult to describe. However, one probable scenario is that a repair crew cannot get to the site of the damaged pipeline because of fire, flooding or other conditions. An alternative solution may be to completely bypass the repair. Repair concepts that are adaptable for both in-crater repair and crater bypass would be appropriate in base recovery.

Flexibility in terms of repairing highly misaligned pipe is essential to any rapid repair effort. Using either a highly flexible replacement conduit or a highly flexible coupler will make pipe misalignment manageable. Use of layflat hoseline, for example, would eliminate the time consuming task normally needed to adjust for horizontal or vertical misalignment. Layflat hoseline is capable of tolerating extensive misalignment as long as it is not kinked. Other characteristics of layflat hoseline are addressed in the discussion section of this report.

7.0 PIPELINE REPAIR CONSIDERATIONS

7.1 Existing Equipment

The Naval Supply Centers operate and maintain the fuel facilities at most Naval bases. They have material and equipment in stock for maintenance and peacetime repair. This includes pipe cutters, air compressors, and vapor indicators (Lower Explosive Limit/Oxygen meters). The repair couplers discussed in this report can augment these resources.

7.2 Repair Personnel

It is difficult to predict who will be available to repair damaged fuel lines in base recovery. It is conceivable that a group of individuals from the list below will be included in a make-shift repair crew. A minimum of three individuals would be needed to safely conduct a repair.

Naval Construction Force
Naval Reserve - Tank Farm Units
Public Works (Public Works Contingency Response Center)
Naval Supply Center

7.3 Interservice Commonality

An important consideration in the development of new equipment for the U.S. military is interservice commonality. In base recovery, the use of "proven" components, such as layflat hoseline and the single-groove quick-disconnect fittings, should be considered. The Marine Corps has successfully used layflat hoseline in its Tactical Airfield Fuel Dispensing System (TAFDS). The U.S. Army, as well as most U.S. services, has successfully used the single groove quick-disconnect fittings on many of their fuel pipelines.

7.4 Repair of Out-of-Round Pipe

The ability of a coupler to effectively seal out-of-round pipe is of great importance in base recovery. As demonstrated in the blast test conducted at Kirtland AFB, eccentricity beyond 4 percent was encountered approximately 12 feet from the bomb detonation point. The extent of distortion several feet from the detonation point will generally exceed the tolerance of all commercially available couplers; commercially available couplers are designed for pipelines with a maximum eccentricity of 2 percent. Couplers capable of sealing out-of-round pipe can minimize repair times by reducing the time required to excavate soil back to in-round pipe, as well as reducing the risk of leakage after the repair is made.

7.5 Velocity

The fuel velocity through pipeline couplers and associated replacement conduits should closely match the velocity prior to damage. High fuel velocities can create hazardous conditions. High velocity may cause static electricity buildup and which could be particularly dangerous at the fuel dispensing point. Replacement sections used in the repair should be close in diameter to that of the pipe being repaired.

7.6 Axial Restraint

Coupler restraint in the axial direction must be considered when using flexible hoseline to repair hard-wall pipeline. Designing a repair that uses either an external or internal coupler must consider the loads induced by pressure and flow (including peak pressures). The induced load acts on the cross-sectional area of both the pipe end, and the coupler. The magnitude of the force is a function of the pipe cross-sectional area and the peak pressure of the distribution system. The coupler must be able to resist the outward force trying to push it off the pipe end. The resultant axial force from a pipe operating pressure of 150 psi on a nominal 6-inch-diameter external coupler is 837 pounds. Considering the design pressure, which includes transient pressure, a force of 1,534 pounds may be experienced. (In hardwall pipeline repair using couplers, the load is nullified because the axial forces counteract each other).

7.7 Layflat Hoseline

Lightweight layflat hoseline has several advantages over carbon steel pipeline for repairing fuel lines in base recovery. The layflat hoseline is made of polyurethane and is resistant to a variety of chemicals, including jet fuels. One of the most important features of the layflat hoseline is its elasticity. It is capable of swelling during pressurization, and can dampen potentially catastrophic pressure surges (see Table 1 for swell characteristic). USAF testing showed that very high pressures (in excess of a 1,000 psi) can result from bomb shock (Ref 2). This indicates that the repaired section of fuel piping could serve as a sacrificial section, making the remaining distribution system survivable to follow-on attack. New hoseline as described by the hoseline manufacturer has a burst pressure of 600 psi. The hoseline is available in a wide variety of sizes, pressure ratings, and applications (such as waterline repair).

8.0 DEVELOPMENT OF NEW REPAIR TECHNIQUES

The three couplers addressed in this report were developed in an attempt to meet the majority of the requirements described above. The cold forge coupler and the internal coupler were developed to exploit the flexibility and portability of layflat hoseline. Consequently, these couplers must have a high axial restraining capability. The inflatable seal coupler was developed to exploit the strengths of lightweight hardwall replacement section (such as aluminum pipe). Consequently, it must be extremely tolerant of pipeline misalignment. The three couplers are described below.

8.1 Cold Forge Coupler

8.1.1 Description of the Cold Forge Coupler and Components

The cold forge coupler consists of three parts: a cold forge coupler, a forging tool, and layflat hoseline with hoseline quick-connectors. See Figures 1 and 2 for a view of the forging tool and coupler.

The cold forge coupler is a one-part unit made with a high strength chromium, molybdenum alloy steel. The coupler has a yield strength greater than the pipe being repaired (approximately 20,000 psi greater). It is fabricated with a series of high-strength ribs on its interior surface, and a single groove on the exterior surface. The ribs are knife-edged and, during the cold forging process, penetrate into the outer surface of the pipe being repaired. The single groove on its outer surface is used to connect a standard quick-connect fitting.

The cold forging tool consists of a high strength expandable rubber sleeve seated over a steel spindle. The tool can be designed to deliver radial pressure in excess of 30,000 psi. Any type of fluid can be used as the pressurizing medium, but a water/glycol mixture was used. The tool can be pressurized by a wide variety of high pressure devices, including a high pressure reciprocating pump.

8.1.2 Description of the Cold Forge Repair Concept

The cold forge coupler repair concept was developed to repair underground pipeline that is out of alignment. The repair process begins by removing the damaged pipe section and cleaning the exposed pipe ends. The coupler is then aligned with the cold forge tool and together they are placed on the pipe end. Next, pressure is supplied to the forging tool, expanding the pipe wall radially outward into the coupler's ribs. During the cold forging process, the pipe is taken beyond its elastic limit, while the coupler remains within its elastic region. When the pressure from the cold forging tool is removed, a compressive force results, holding and sealing the pipe and coupler together by creating a series of metal-to-metal seals. This joint is permanent, structurally sound, and pressure tight. A second coupler is forged to the other pipe end using the same process. Layflat hoseline can then be connected to the single groove connectors of the cold forge couplers to complete the repair.

8.2 Internal Coupler

8.2.1 Description of the Internal Coupler and Components

The internal coupler repair consists of two parts: an internal coupler and layflat hose with hoseline quick-connects. See Figure 3 for a view of the internal coupler.

The internal coupler consists of the following components. See Figure 4 for a cross-sectional schematic.

Expanding wedge collar
Seal(s)
Solid wedge cone collar
Nut sleeve
Push collar
Collar
Turning handles
Main shaft

8.2.2 Description of the Internal Coupler Repair Concept

The internal coupler concept was developed to rapidly repair pipelines that are extensively misaligned. The internal coupler is attached to the inner pipe surface by using the mechanical advantage of the power screw and wedge principle. The coupler uses the pressure of the operating medium to seal the pipe and coupler together. In general, fuel lines are in better condition on the inside than on the outside. The internal coupler exploits this condition, and eliminates the need to remove coating on outside of the pipes.

The repair process begins by removing the damaged pipe section and cleaning the exposed pipe ends. The coupler is inserted into the pipe end. It is secured to the inner pipe surface by holding the primary handle steady, while turning the secondary handle clockwise (see Figure 5). By turning this handle, an axial force is generated and is converted into an outward radial force by means of the wedge cone collar. This action pushes the expandable wedge collar into the inner pipe surface. This mechanism provides the coupler's axial restraint. The axial force, at the same time, compresses and extrudes the dual rubber seals to fill the annulur gap; this then seals the pipe and coupler together. The internal coupler employs the pressure of the fluid flow on the cross-sectional area to further secure itself to the inner surface of the pipe. This joint is expected to be structurally sound and pressure tight. A second coupler is installed on the other pipe end, and a layflat hose connects them to complete the repair.

8.3 Inflatable Seal Coupler

8.3.1 Description of Inflatable Seal Coupler

The inflatable seal coupler consists of an inflatable seal (complete with valve stems) and constraining shell. The inflatable seal is made out of a high strength fuel resistant rubber. The constraining shell is a short length of aluminum pipe tapped with a small hole to accept the valve stem. For testing purposes, a schedule 10 aluminum pipe was used.

Since the inflatable seal has minimal capabilities for resisting axial motion, a section of lightweight aluminum is used as the replacement section rather than layflat hoseline.

8.3.2 Description of the Inflatable Seal Repair Concept

The inflatable seal coupler concept was developed for rapidly repairing pipeline that is out-of-round and/or misaligned (see Figure 6). The repair process begins by removing the severely damaged (restricted flow area) pipe and cleaning the exposed pipe ends. This is followed by measuring and cutting a lightweight aluminum section to size as shown in Figure 7. The next step is to install the inflatable seal coupler over the pipe end and then over the replacement section as shown in Figures 8 and 9. The seal can then be inflated to 150 psi (see Figure 10). Flow can then be resumed in the fuel line. See Figure 11 for completed repair configuration.

9.0 CRITERIA FOR EVALUATING FEASIBILITY

Since proving coupler feasibility was the main objective of this evaluation, the criteria as established in the decision point review was based on (1) coupler effectiveness and (2) speed of installation.

9.1 Effectiveness

The criterion established for determining coupler effectiveness was based on the Naval Facilities Guide Specification NFGS-15486 "Aviation Fuel Distribution and Dispensing." The specification calls for a minimum proof pressure of 275 psi for fuel lines when constructing new distribution systems. For purposes of this evaluation, an installed coupler that could hold 275 psi pressure for 10 minutes was considered to be acceptable.

9.2 Speed of Installation

The criterion established for determining the speed of pipeline repair in base recovery was based on the Air Force Draft Statement of Operational Requirement. This document specified a 20-minute repair time after pipe ends are exposed for repair. Since the 20 minutes include cutting off the bomb-distorted pipe end and other necessary tasks, it was determined that a coupler would have to be installed in less than 5 minutes. For this evaluation, only couplers that could be installed in less than 5 minutes were to be considered acceptable.

10.0 EXPERIMENTAL TEST SETUP AND PROCEDURES

10.1 Cold Forge and Internal Coupler

The test setup for the cold forge coupler and the internal coupler consisted of a static pressure test stand as shown in Figure 12. Proving feasibility was the main objective of the test. Only one pipe size and material was chosen: a 6-inch schedule 40 carbon steel pipe. An end cap with a quick disconnect fitting was used to perform a static pressure test. For safety and environmental concerns, the line was pressured with water instead of jet fuel.

10.2 Inflatable Seal Coupler

The test setup for the inflatable seal coupler was a pipe network made of 4-inch-diameter pipeline. Hydrostatic tests for this repair technique were accomplished by pressurizing the inflatable seal and pipe network with water. The pipes used for the test setup were carbon steel, ASTM-53B, plastic coated and non-coated, 4-inch schedule 40. To evaluate coupler performance on an out-of-round pipe, the circular cross sections of two pipes were changed to oval cross sections with minor diameters of 3 inches and 3.5 inches, respectively. The repair method was evaluated for pipelines with the pipe coupler configurations shown in Table 2. Axial misalignment is shown in degrees. When plastic coated pipes were used in the test, "plastic" is noted.

11.0 TEST RESULTS

11.1 Cold Forge Coupler

The cold forge coupler and ancillary quick-connect fitting were installed within 2 minutes and 50 seconds. This represents one half of a repair to a severed pipeline. The installed coupler was hydrostatically tested above 275 psi for 10 minutes without leakage. The test cap was removed and the coupler was inspected for signs of visible failure; none were found.

11.2 Internal Coupler

The internal coupler and test cap were installed on a nominal 6-inch-diameter pipe within 1 minute and 20 seconds. This also represents one half of a repair to a severed pipeline. The installation process was conducted by just one man in simulating a ground-based pipeline repair.

The installed coupler was hydrostatically tested above 275 psi for 10 minutes with no leakage. The coupler was removed and visually inspected. No visible signs of cracks or tears were found on the coupler or seal.

11.3 Inflatable Seal Coupler

The inflatable seal coupler concept was tested up to a static pressure of 400 psi, as shown in Table 2. Misalignment is shown in number of degrees from axial alignment. Static pressure was held in the pipeline for a minimum of 10 minutes. Although a burst pressure was not part of formal testing, an inflatable seal was pressure-tested to failure to determine overall burst strength. The inflatable seal ruptured at the valve stem at 650 psi.

One seal was severed by the end of the pipe when it was configured for a repair with 16 degrees misalignment.

12.0 DISCUSSION

Subsequent to development of the three couplers, improvements, as well as spinoff concepts, have been pursued. These improvements and spinoffs are considered as design challenges outside the scope of this report. These improvements have not been field-tested, but are felt to be worthy of further study. They are discussed below because they show promise in enhancing the capability of the couplers tested.

12.1 Cold Forge Coupler Alternative

At the conclusion of the cold forge feasibility test, a new concept was developed to significantly reduce the weight of the coupler and the cold forging tool (see Figure 13). The weight of the coupler could be significantly reduced by decreasing the length of the coupler. In addition, an alternative material, such as aluminum, could be used for most of the coupler. Analysis indicates that a reduction of overall coupler length and the use of aluminum could reduce the coupler weight by 40 percent without affecting its ability to hold the specified pressures.

Another concept for a cold forging tool is shown in Figure 14. The concept is based on the wedge principle central to the internal coupler. Instead of using a power screw, it uses a dual action hydraulic jack, eliminating the need for a dedicated electrically powered supply system.

12.2 Internal Coupler Alternative/Improvements

An alternate concept to the internal coupler is shown in Figure 15. Instead of attaching the coupler to the inside of the pipe, it would be attached to the outside. This would minimize the flow restriction and pressure-reducing features of the internal coupler. The external coupler would use the same basic seal and wedge concept as the internal coupler.

12.3 Inflatable Seal Coupler Alternative

Figure 16 shows an advanced inflatable seal concept for high pressure applications. It differs from the inflatable seal only with respect to the constraining shell. The constraining shell fully surrounds the inflatable seal. Since the inflatable seal is fully contained, it is capable of handling dramatically higher pressures.

13.0 CONCLUSIONS

The exploratory development efforts completed to date indicate that each of the couplers is feasible for rapid fuel line repair in base recovery. The cold forge coupler was successfully installed in less than 3 minutes by two men, and maintained a hydrostatic pressure of 425 psi. The internal coupler was successfully installed by just one person in less than 2 minutes. It maintained a pressure of 275 psi without leakage, and would handle the typical pressures found at Naval fuel installations. The inflatable seal coupler was especially successful in holding pressure on pipeline that was out-of-alignment and/or out-of-round.

Overall logistics (when compared to conventional repair methods) is improved significantly because the repair does not require using heavy material handling and transport equipment. In general, two men can repair a pipe rapidly with minimal support equipment.

The relative merits of the three pipeline repair techniques for base recovery can be summarized as follows

13.1 Cold Forge Coupler

Overall repair time (when compared to conventional repair methods) is reduced drastically since:

(1) The repair technique is not dependent on pipe ends being aligned, thereby decreasing excavation efforts normally needed to reach undamaged, aligned pipe. Also the physical task of aligning a heavy replacement section is eliminated since layflat hoseline is used.

(2) The time-consuming task of cutting a carbon steel replacement pipe is eliminated since layflat hoseline is used.

13.2 Internal Coupler

Overall repair time (when compared to conventional repair methods) is reduced significantly since:

(1) The repair technique is not dependent on pipe ends being aligned, thereby decreasing excavation efforts normally needed to reach aligned pipe. Also the physical task of aligning a heavy replacement section is eliminated.

(2) The time-consuming task of cutting a carbon steel replacement pipe is eliminated since layflat hoseline is used.

(3) No tools are needed for installation.

(4) No coating removal is required since the coupler is installed internally.

13.3 Inflatable Seal Coupler

Overall repair time (when compared to conventional repair methods) is reduced significantly since:

(1) The repair technique is not dependent on pipe ends being aligned or in-round; the inflatable seal coupler takes the shape of the distorted pipe cross section. Excavation efforts normally needed to reach aligned pipe can be dramatically reduced as a result.

(2) The physical task of cutting and aligning a heavy replacement section is eliminated. The aluminum replacement section can be rapidly cut with a simple hacksaw and installed by one person.

(3) No coating removal is required as for commercial couplers.

14.0 RECOMMENDATIONS

It is recommended that advanced development of these rapid pipeline repair couplers be conducted. This would include coupler refinement and further engineering testing and evaluation. Testing parameters would include cyclic testing under different temperature conditions. Each of the couplers should be evaluated for repairing stainless steel and aluminum pipe. Other testing should include evaluating coupler performance on pipeline of different external conditions and age (corroded and pitted).

It is also recommended that the couplers be evaluated under dynamic loading using jet fuel or a medium that has a closer viscosity to jet fuel.

Recommendations for further improvement of the individual couplers are as follows:

14.1 Cold Forge Coupler

(1) Reduce the forging tool weight to less than 75 pounds. This can be accomplished by hollowing the tool and reducing its length by 30 percent.

(2) Reduce the weight of the coupler. This can be accomplished by using aluminum for most of the material and shortening the length of the coupler by 33 percent.

14.2 Internal Coupler

(1) Reduce the weight of the coupler. This can be accomplished by using aluminum for most of the material and also shortening the length of the coupler by 25 percent.

(2) Design, fabricate, test, and evaluate an external coupler version.

14.3 Inflatable Seal Coupler

(1) Evaluate the coupler for repairing other types of pipelines (sewer and natural gas).

REFERENCES

1. Petroleum Fuel Facilities. Design Manual 22, NAVFAC DM-22, Department of the Navy, Naval Facilities Engineering Command, Alexandria VA, August 1982.

2. U.S. Air Force Weapons Laboratory. WL-TR-89-40: Shock-Induced Pressure Transient in Pipelines, by J. D. Heminger and L. T. Nicholas, Kirtland AFB, NM, November 1989.

Table 1
Outside Diameter of Layflat Hoseline
With Increased Static Pressure

Pressure (psi)	Outside Diameter (in.)
5	6.21
50	6.64
75	6.69
100	6.72
125	6.73
150	6.78
175	6.86
200	6.94

Table 2
Inflatable Seal Coupler Configurations and Maximum Static Pressure Held

Pipe Condition	Misalignment (deg)	Joint Configuration	Pressure (psi)
Round	0	Steel to Steel	400
Round	0	Steel to Plastic	400
Round	8	Steel to Steel	250
Round	16	Steel to Plastic	385
1/2-in. Reduction along one axis	4	Steel to Plastic	250
1-in. Reduction along one axis	4	Steel to Plastic	250

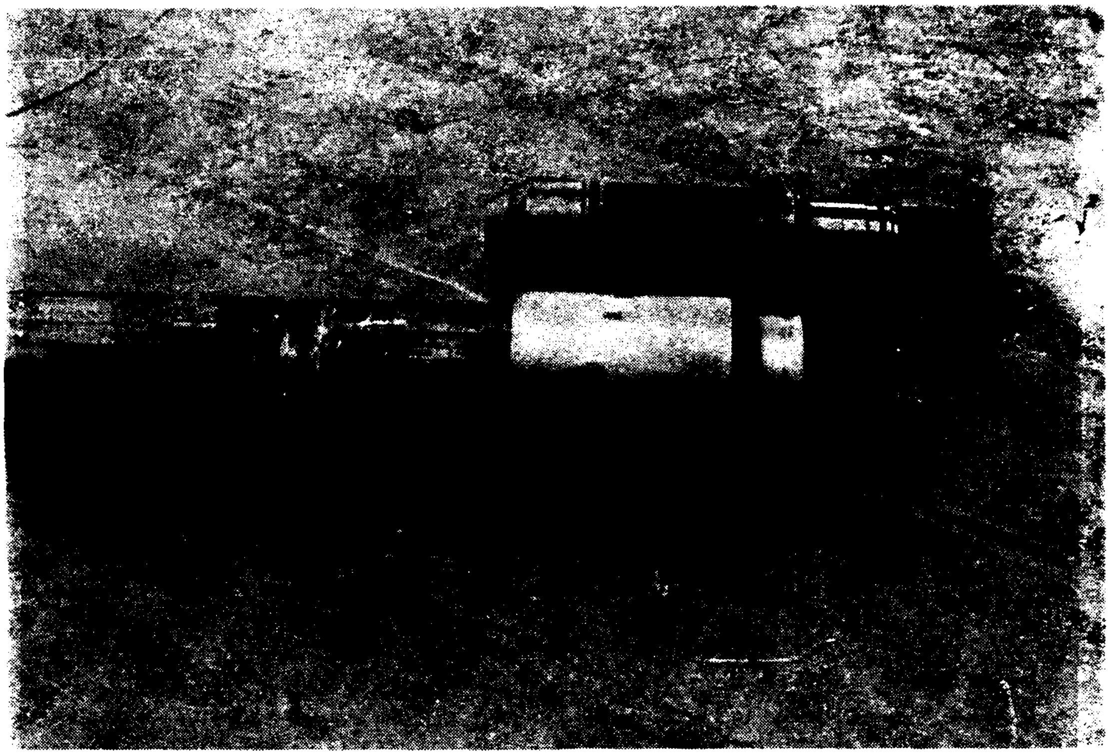

Figure 1. Cold Forge Coupler (bottom) and Tool (top)

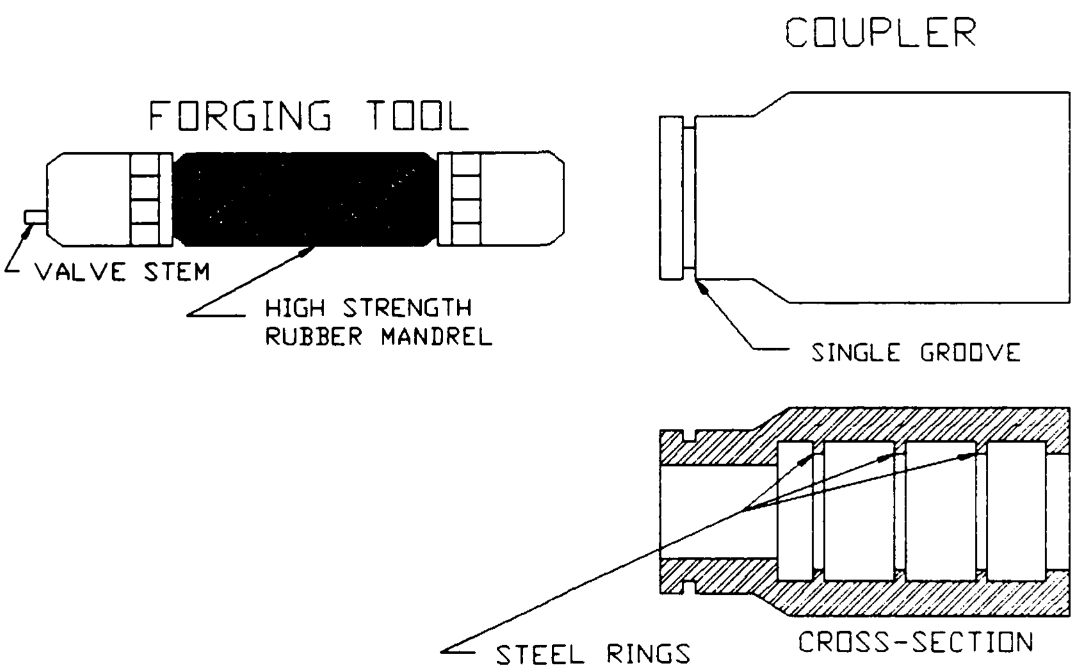

Figure 2. Cold Forge Coupler and Tool Cross Section Schematic

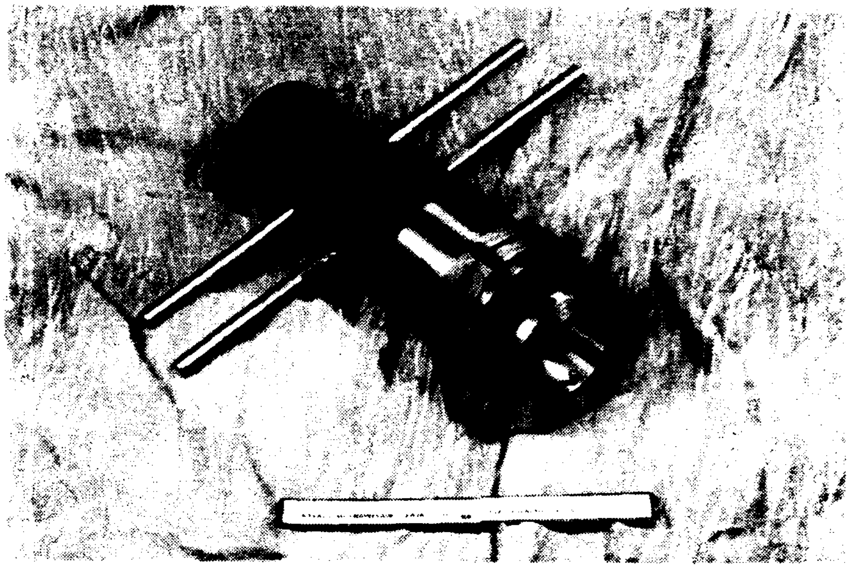

Figure 3. Experimental Internal Coupler

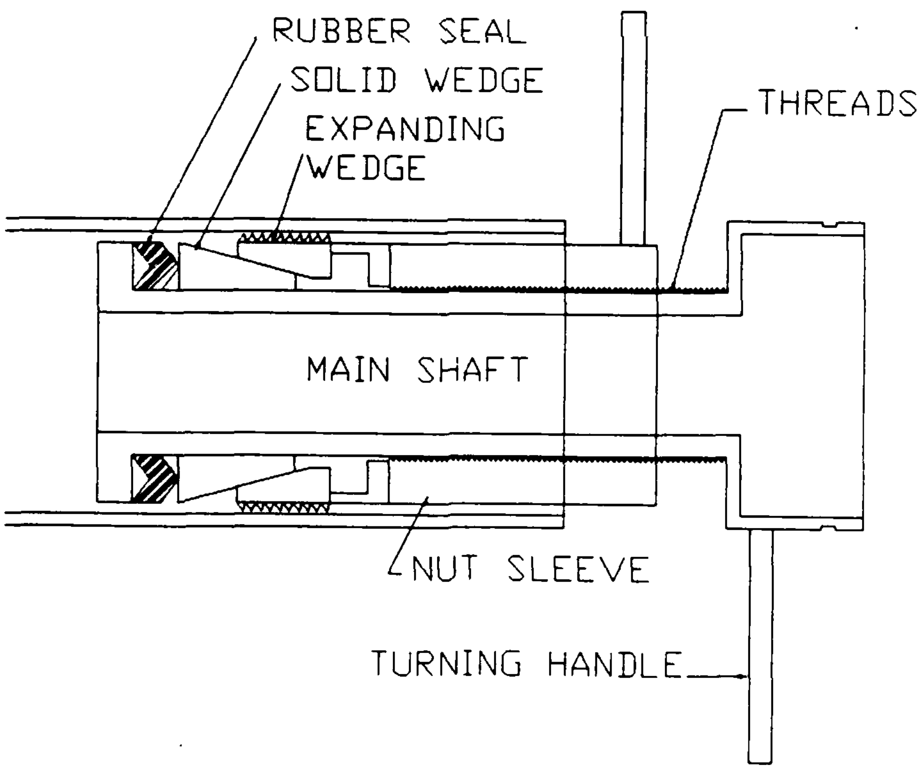

Figure 4. Schematic of Internal Coupler

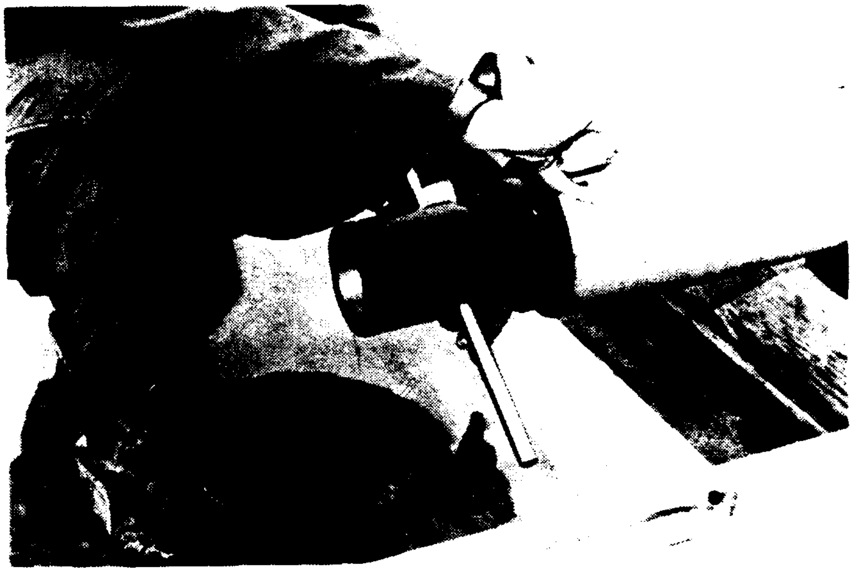

Figure 5. Installing Internal Coupler

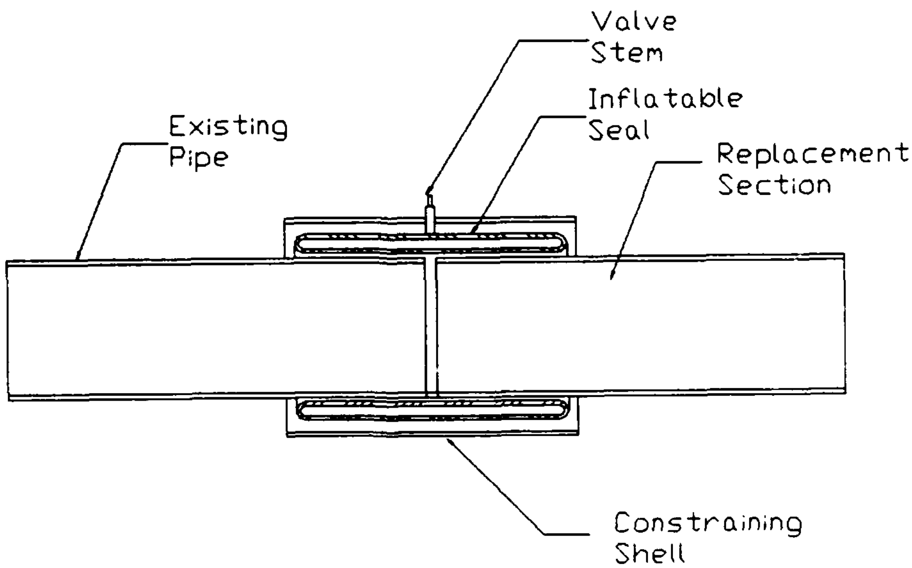

Figure 6. Schematic Inflatable Seal Coupler

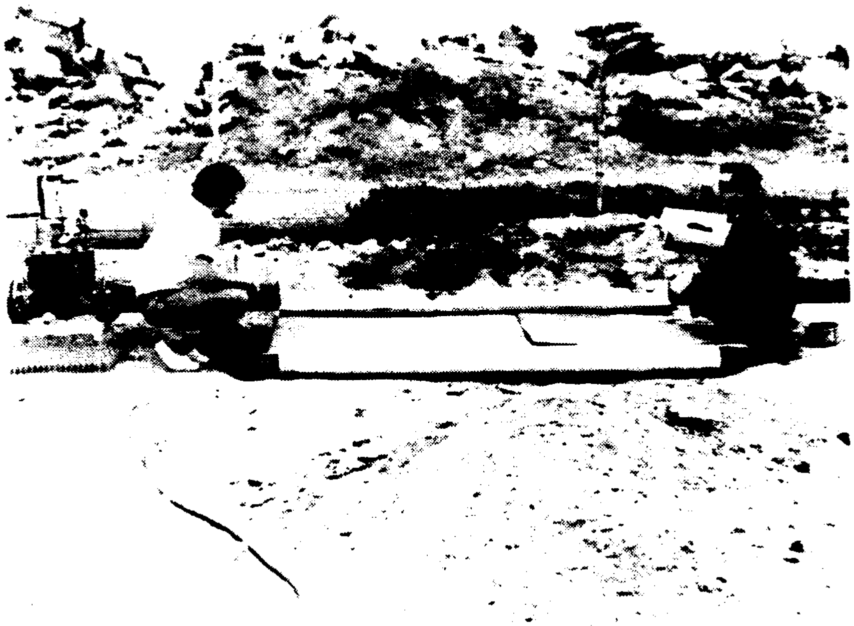

Figure 7. Measuring Cut-to-Fit Length

Figure 8. Installing Inflatable Seal Over Existing Pipe

Figure 9. Installing Inflatable Seal Over Replacement Section

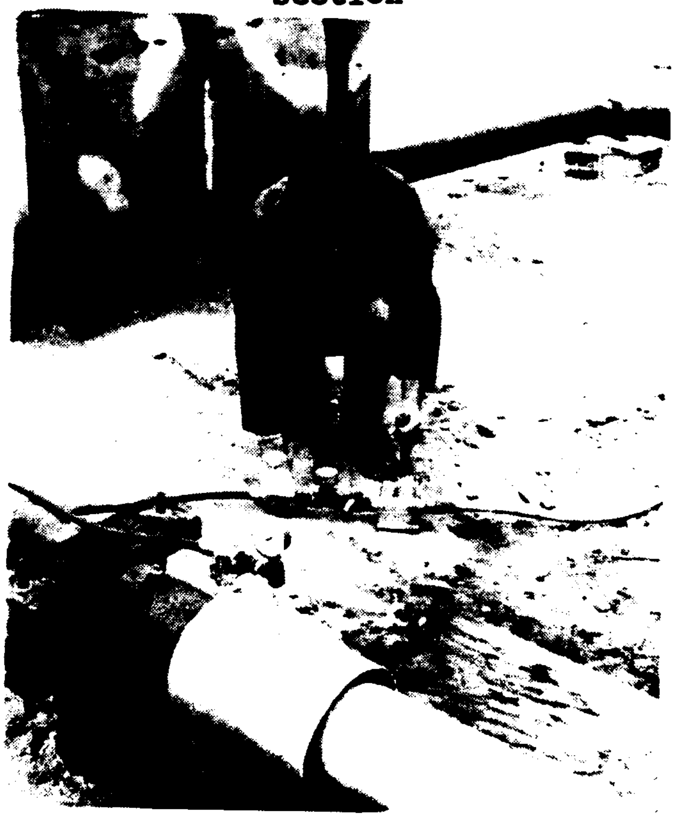

Figure 10. Inflating the Seal With Manual Pump

Figure 11. Completed Inflatable Seal Coupler Repair

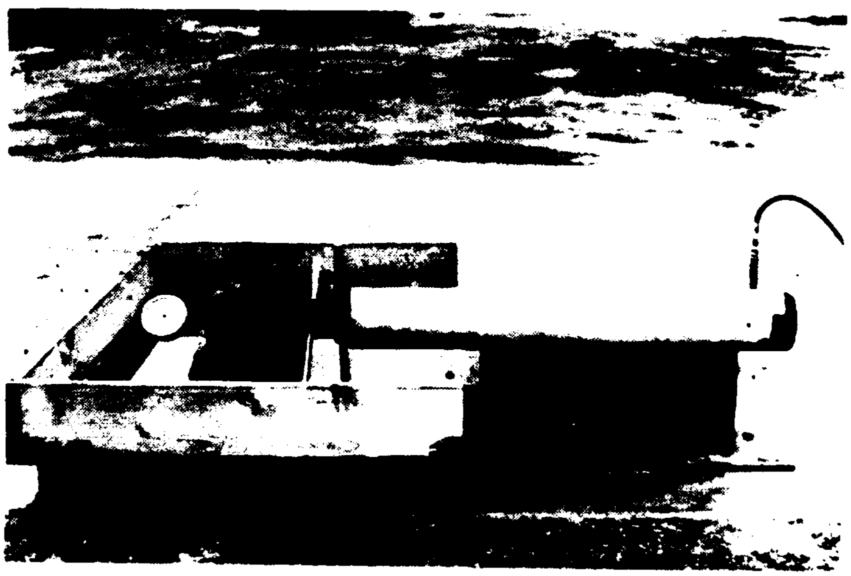

Figure 12. Testing of Internal Coupler

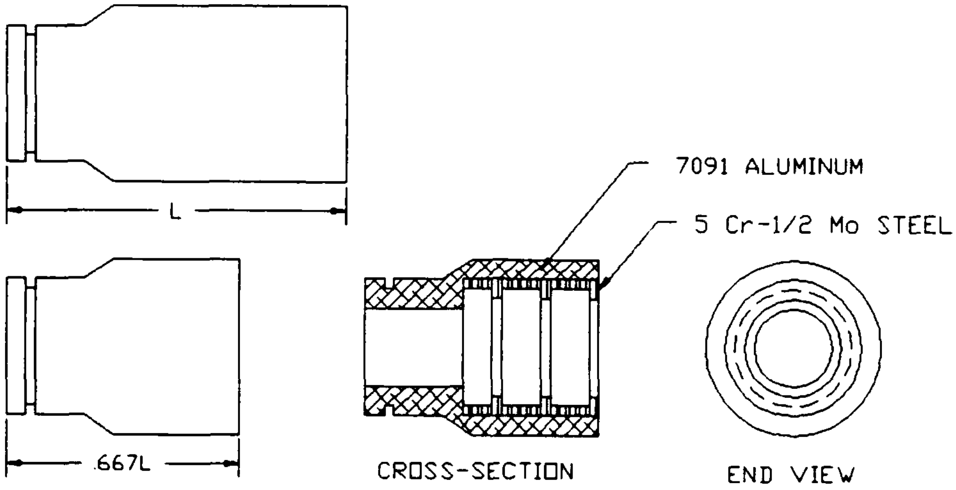

Figure 13. Cold Forge Coupler Cross Section Schematic

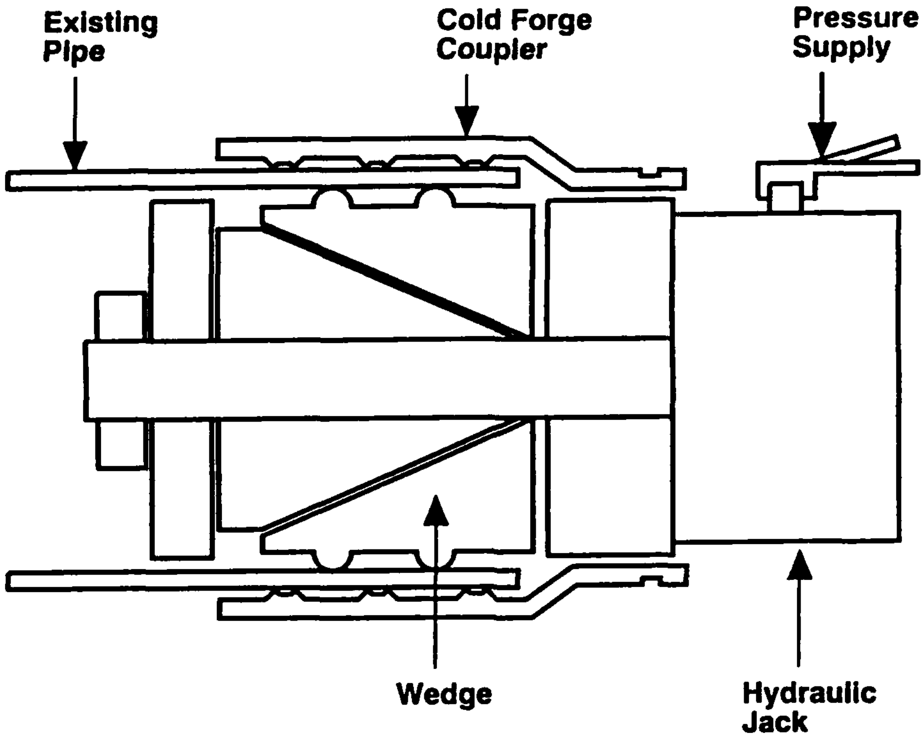

Figure 14. Cold Forge Tool Cross Section Schematic

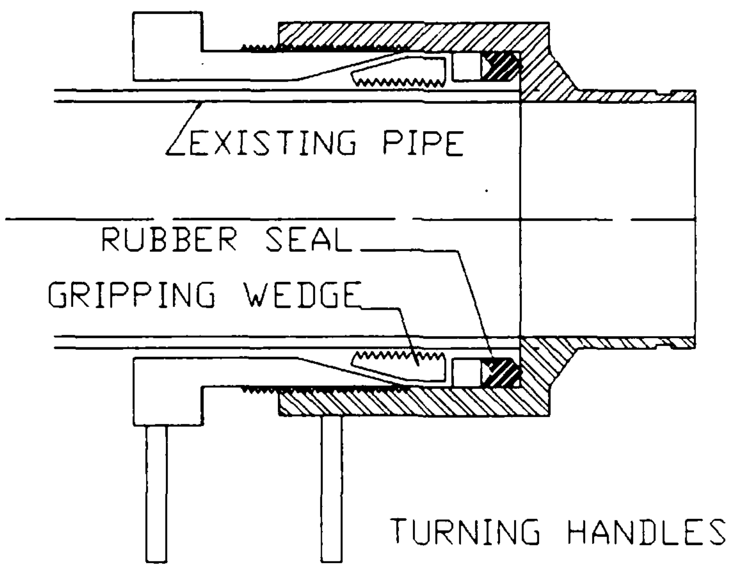

Figure 15. Conceptual Drawing of External Coupler Concept

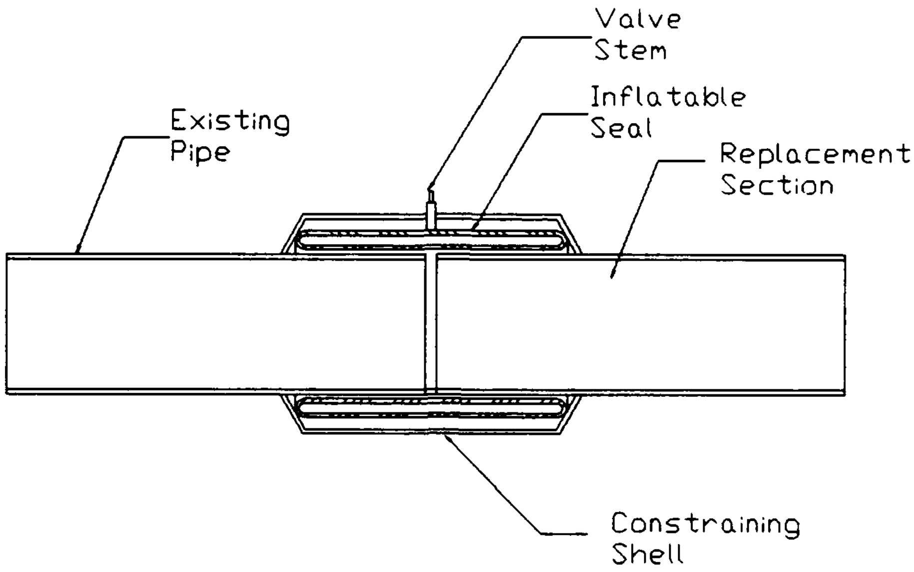

Figure 16. Advanced Inflatable Seal Coupler Concept

Appendix A

KNOWLEDGE BASED SYSTEM FOR EXPEDIENT REPAIR OF POL FACILITIES

TM No. M64-91-01

NCEL Technical Memorandum

Title: KNOWLEDGE BASED SYSTEM FOR EXPEDIENT REPAIR OF POL FACILITIES

Author: PAUL SEIDL AND GARY ANGUIANO

Date: MARCH 1991

Sponsor: OFFICE OF NAVAL TECHNOLOGY

Program No.: PE 62233N

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

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LIST OF FIGURES

BACKGROUND

The capability to quickly repair damaged fuel lines is of critical importance at Navy bases. Following a conventional bomb attack in which portions of the fuel distribution system are damaged or destroyed, meeting the aircraft fueling requirements is a primary concern. The Naval Civil Engineering Laboratory (NCEL) has been tasked by the Office of Naval Technology (ONT) to explore means of quickly restoring mission critical Petroleum Oil Lubricant (POL) pipelines.

Fuel systems at many Naval Air Stations are beyond their intended service life. This translates into a frequent need for repairs. Other compounding problems include the high turnover rate of military personnel and the lack of training in rapid repair of damaged pipelines. To combat these problems, NCEL, through parallel efforts, has developed (1) techniques and hardware for expedient, temporary repair of POL facilities, and (2) a knowledge based advisor model for assisting users in making the most expedient temporary repairs to bomb-damaged POL pipelines. The specialized hardware, along with other standard components necessary for pipeline repair, has been compiled in a repair kit called HIT-FASST (Hydraulic Integrated Tools Field All-purpose Support SysTem). The knowledge based advisor model was developed to assist the operator in making expedient, temporary POL pipeline repairs using the HIT-FASST.

Because the advisor contains information gathered from interviewing various experts in industry, it replaces cumbersome repair manuals and stacks of blueprints normally used to make repairs. Since the probability of an expert being on hand immediately after an attack to solve a problem is small (a classic example of the need for knowledge based system technology), the system provides the user with easy-access text, graphics, and illustrations of the best way to make repairs the same way an expert would. Detailed information that is not commonly known about safety considerations, fuel fire-fighting, specialized repair techniques, etc., is readily available from the advisor model. This memorandum describes the structure and functionality of the experimental knowledge based advisor model developed by Combat Support Systems Division, Code L64, NCEL.

OBJECTIVE

The objective of the experimental knowledge based system was (1) to determine whether a cost effective, light weight, user-friendly, knowledge based advisor could be developed for the purpose of assisting personnel in the expedient, temporary repair of bomb-damaged fuel facilities, and (2) to determine the effectiveness of such as a system to military personnel (Seabees, reservists, public works personnel, etc.).

PROGRAM DESCRIPTION

The knowledge based system for expedient repair of POL facilities consists of text, graphics and illustrations that can be used to expedite the repair of damaged fuel facilities. It can be utilized by operators with any degree of expertise, from the novice who is unfamiliar with the base, to the experienced technician who knows the facilities thoroughly.

The body of the program is made up of two commercial software packages: 1st-Class HT (an expert system shell) and AutoCad (a computer aided drawing package). The 'HT' stands for Hypertext, which is a special feature that allows the user to make jumps within a document to either other text or illustrations. This is analogous to flipping through pages of various volumes of handbooks or manuals. But with hypertext, the high speed graphics interface and data retrieval all happens at the touch of a key. The user can quickly and easily jump from instructions on operating a specialized tool, such as a pipeline locator, to viewing plans of the fuel system and runways, to viewing an illustration of how to perform the most expedient pipeline repair.

As the program begins, the user views the Main Menu, where five main options are presented. The user has the option of selecting system Operating Instructions, HIT-FASST Equipment Instructions, Pipeline Repair Instructions, Base Graphics and Facilities Data, or Exiting the system.

The first main option, HIT-FASST Equipment Instructions, contains instructions on how to operate the specialized tools and equipment that have been designed for expedient repair of POL pipelines. If the user selects this first menu item, a list of the special repair equipment is presented. From that list, the user can select any of the equipment that he is unfamiliar with and receive instructions on the proper use of that item. Illustrations are available when called upon. It is in this way that the system is sensitive to the operator's level of expertise. The only information presented is the information needed by that particular operator.

The second main option, Pipeline Repair Instructions, contains instructions regarding the actual repair of bomb damaged pipelines. After selecting this main option, a few important precautions are presented. Then, the user is prompted to check for the presence of a redundant pipeline path to reroute the fuel. If there are no redundant paths, the Pipeline Repair Instructions submenu is presented. It contains three suboptions: In-crater Fire Fighting, In-Crater Pipeline Repairs, and Crater Bypass. Each suboption contains step by step instructions on performing the specified task. Illustrations are included in the instructions when called upon.

The third main option, Base Graphics and Facilities Data, contains graphic and textual information about the base. The user can choose between viewing the entire base (see Figure 1) or instantly zooming in for a close up of one particular area. Different isolated components of the base, such as just the fuel system, water lines, and runways, can also be viewed (see Figure 2). Additionally, the components of the fuel system are labeled (see Figure 3) with an Equipment Reference Number (ERN). The user can select the DATA option from the Graphics menu and, after inputting the ERN for a certain fuel system component, examine specific data and illustrations of that item.

The other options in the main menu are Advisor Instructions and Quit Advisor.

PROGRAM DEVELOPMENT

The development of the model knowledge based system involved customizing and linking two separate software packages: 1st-Class HT and AutoCad. Additionally, a product called Video Velocity was integrated with AutoCad to enhance its performance. Each module was developed separately and then joined together to form the final program.

The software package 1st-Class HT uses hypertext, a database management tool, to enable the operator to make logical connections of information at the touch of a button. These logical connections, or links, are made across and within preset files of text that were created using the resident 1st-Class HT editor. A network of links was created to form a large number of possible paths for the user to follow, depending on his instructional needs and level of expertise.

In order to get from one screen to another, 'buttons' were set up to prescribe each logical link. To activate these links, the user must position the highlighted bar on the desired menu item and press the ENTER key to select it. This can be done in two ways. The standard functioning of 1st-Class HT involves positioning the highlight bar with the Up and Down arrow keys on the keyboard. Additionally, mouse functionality was added by the inclusion of the file MOUSE.COM (from the MicroSoft Mouse source disks) and the file MENU.COM (from the 1st-Class HT source disks). With this added feature, the user can simply move the mouse so that the cursor on the screen is highlighting the desired menu item, and then click the left mouse button once (same as pressing the ENTER key) to select it. Clicking the right mouse button once backs up one screen (same as pressing the ESCAPE key).

Along with textual information, hypertext buttons can also link with illustrations. The illustrations in the expert system were created by scanning black and white drawings using a Hewlett-Packard Scan-Jet Plus Model 9195A. These scanned images, in the form of '*.PCX' files, were then painted (for clarity) using software called Pictor. The painted *.PCX files are directly accessed by 1st-Class HT using an executable file called SHOWPIC.EXE.

Because there is so much detail needed when displaying the map of the air station, it was necessary to integrate a vector graphics package into the knowledge based system, rather than rely on the pixel images produced by Pictor. The vector package needed must be able to quickly zoom in and pan large, detailed drawings. Because AutoCad can manipulate existing Navy graphic databases and is widely used and understood, it was chosen as the tool to display the base graphics. When the user chooses to view a particular drawing, an executable file called AS.EXE is invoked to automatically swap out 1st-Class HT from memory and load in AutoCad. Once loaded, a batch file called START.SCR calls up the requested drawing.

In order to provide the functionality needed by the user while in AutoCad, AutoLisp was used to create a custom menu. This custom menu was substituted for the regular ACAD.MNU file and permits the user to ZOOM, PAN, display textual DATA, DISPLAY only the utilities, get system HELP, or EXIT from the graphics portion of the system.

While examining the selected drawing in AutoCad, the user may choose to view textual data describing components of the fuel system. This was made available by adding Equipment Reference Numbers (ERNs) to various components and creating a macro, using AutoLisp, that shells out to DOS and displays the text file with the corresponding ERN. When the user is finished with the file, the system returns to the AutoCad environment. This method provides large amounts of information while keeping the drawing free of excess clutter. A menu selection entitled HELP functions in the same way. When selected, a file called HELPER.TXT is displayed. It gives the user instructions on operating the graphics system. When finished, the system again returns to the AutoCad environment. The user can select EXIT from the menu, and the system exits the AutoCad environment and returns to the system main menu.

DISCUSSION

During initial development, the advisor consisted solely of 1st-Class HT linked with AutoCad. While examining the feasibility of the system, it became obvious that AutoCad, by itself, was not exactly suitable for this application. Normally, AutoCad will execute a regeneration when panning or zooming in or out a great distance. To avoid this time consuming procedure, a product called Video Velocity was added to AutoCad to suppress the regenerations during zooms and pans. Video Velocity helps AutoCad provide nearly instant pans and zooms, thus optimizing the performance of the graphic interface.

Other feasibility questions, such as cost effectiveness, weight, user-friendliness, storage capacity, and overall usefulness of a knowledge based system in the base recovery arena, were answered during the development.

The cost of the software for a full-functioning version of the advisor is:

1st-Class HT - $2500. The run-time version of 1st Class HT was included with the initial software purchase. Therefore, any 1st-Class programs developed at NCEL may be distributed at no extra cost.

Video Velocity - $495. This is a fixed cost per knowledge base.

AutoCad Rel. 9 or higher - $2500. This cost can be avoided if existing copies of AutoCad are available.

Pictor - $250. Pictor contains a file called SHOWPIC.EXE that is used as a display engine for the illustrations.

DOS 3.0 or higher - $100. This cost can be avoided if existing copies of DOS 3.0 or higher are available.

* Preliminary testing at NCEL shows that the advisor model is user-friendly enough for an inexperienced computer operator to use after just a few minutes of instructions. This will be examined further during the on-site demonstration at NAS Adak.

CONCLUSIONS

The experimental model knowledge based system for expedient repair of POL facilities shows promise as a functional tool to aide military personnel in expedient repair of bomb-damaged fuel facilities. The development has produced a high-speed database and graphics interface, while providing user-friendliness and detail.

The system could also be utilized both as a repair crew training aide and as a public works reference tool.

RECOMMENDATIONS FOR FURTHER DEVELOPMENT

1. Complete the experimental model into a full functioning POL pipeline repair tool. This will require additional instructions, illustrations, and textual data.

2. Expand the system to include information and repair techniques for different critical components of the air station, such as runways, electric lines, water pipelines, steam pipelines, etc.

3. Eliminate the use of AutoCad and substitute software capable of simply displaying AutoCad drawings. This would improve the speed of displaying the drawings as well as reducing the size and price of the system. The next revision of Video Velocity, currently being finished, has this feature.

POINT OF CONTACT

For further information or demonstration of the knowledge based advisor model, contact:

Paul Seidl, Code L64
Naval Civil Engineering Laboratory
Port Hueneme, CA 93043
805-982-1973
Autovon 551-1973-5003

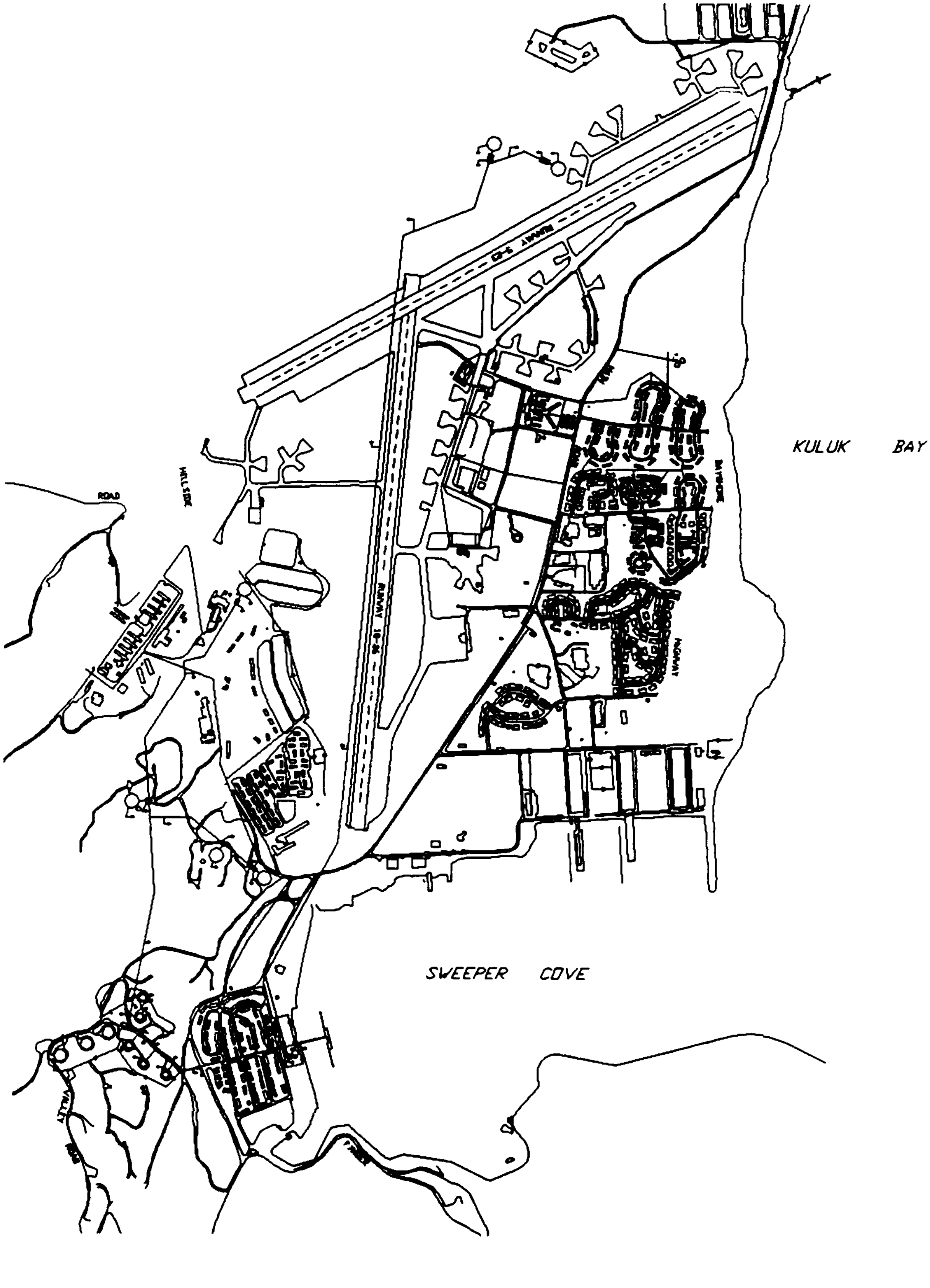

Figure 1 - Full Base View

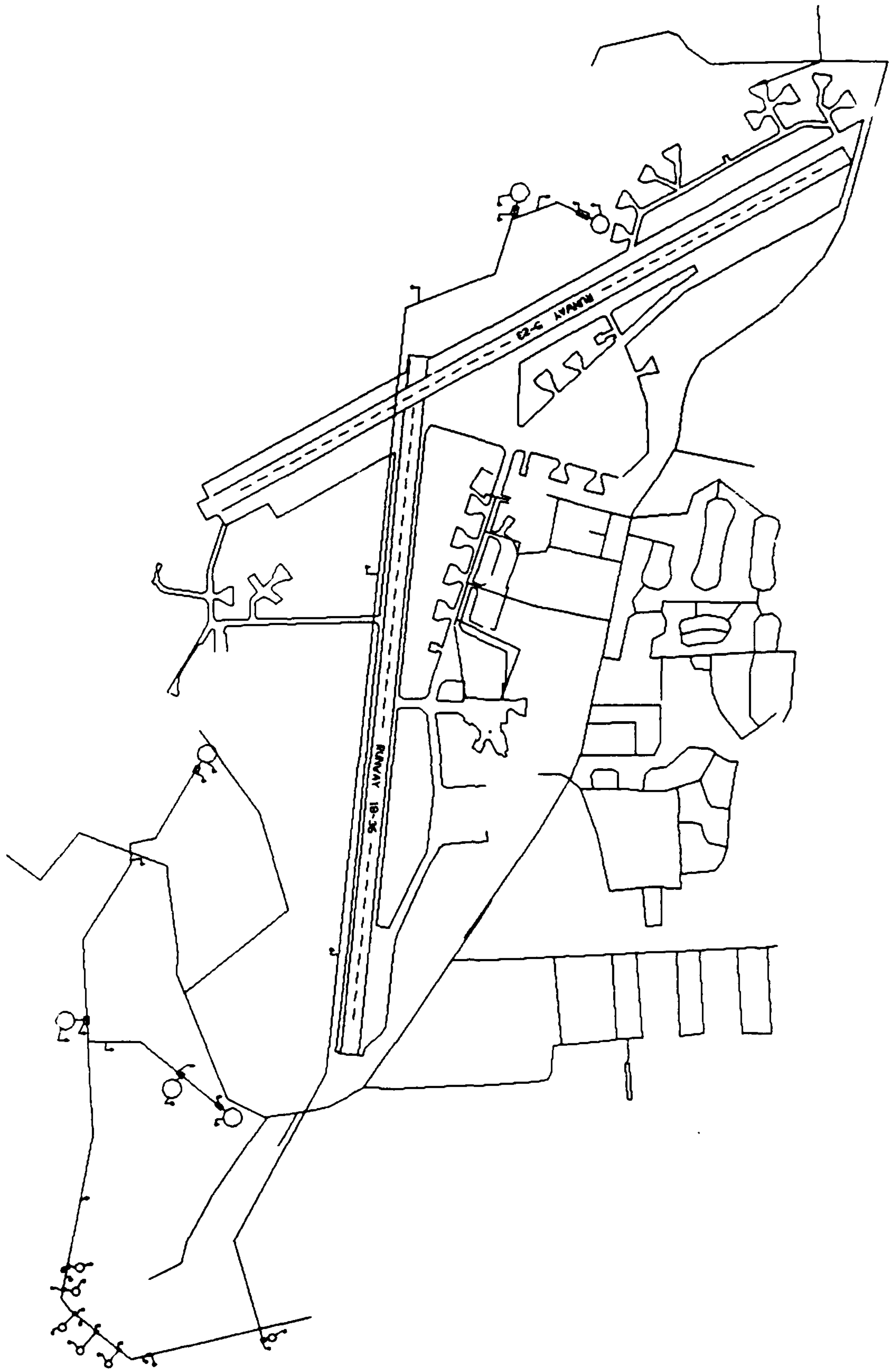

Figure 2 - POL & Water Lines and Runways

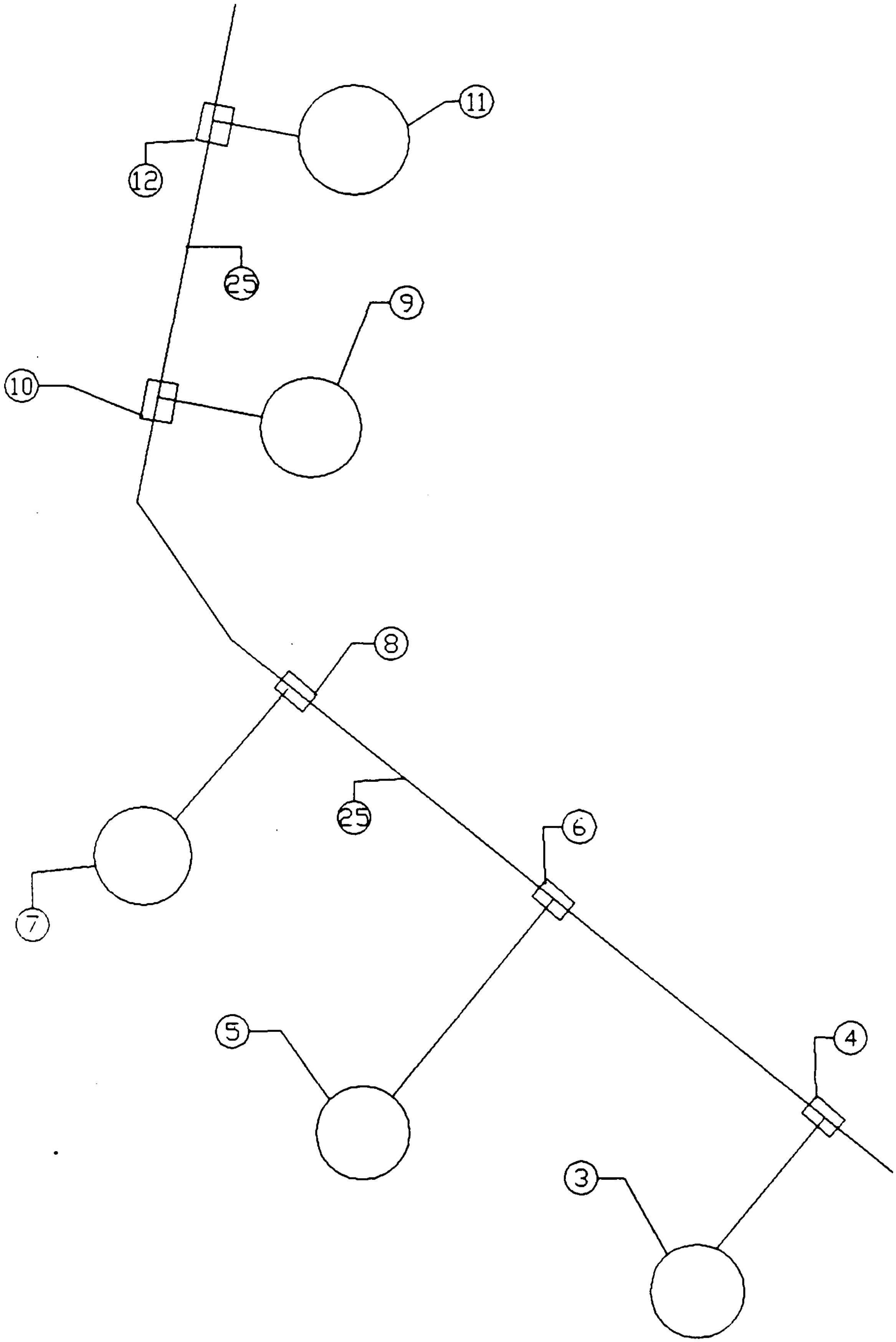

Figure 3 - Fuel Distribution System with Equipment Reference Numbers

APPENDIX

System Requirements

Proper operation of the system requires:

* An IBM PC, Compaq or 100% IBM compatible computer.
* 640 Kilobytes of RAM
* 80287 or 80387 floating point math coprocessor.
* EGA/VGA graphics card with at least 256K of memory.
* Hard disk drive.
* Mouse (optional)
* DOS 3.0 or greater.
* AutoCAD Rel. 9, 10 or 11 using ADI v3.1 or ADI v4.0.

Custom File Arrangement

In addition to having Video Velocity, AutoCad, and the run-time portion of 1st-Class HT each setup and running in their own directory, other files are needed to run the model properly. They are listed below in their proper directories.

C:\ACAD	C:\CLASS	C:\DOS
INFO.LSP	ADVISOR.KBM	ANSI.SYS
HELPER.LSP	PIC1.PCX	
POLH2O.LSP	:	
SHOWALL.LSP	PIC7.PCX	
START.SCR	MOUSE.COM	
CUSTOM.MNU	MENU.COM	
SHOWPIC.EXE	AC.BAT	
C:\ACAD\TEXTFILE	EXP.BAT	
1.TXT	INSTRUCT	
2.TXT	EQPLIST	
:	REPAIR_	
26.TXT	GRAPHICS	

The line DEVICE=C:\DOS\ANSI.SYS /k must appear in the CONFIG.SYS file. The 'k' must be lower case. MOUSE.COM is a file that comes from the Microsoft-Mouse source disks. MENU.COM comes from 1st-Class HT. ANSI.SYS is a DOS file. The rest of the files are custom made.

Running The Program

After setting up the files in the directories as outlined above, and assuming that AutoCad and Video Velocity have been installed properly, the knowledge based advisor model should be started by typing the command EXP and then pressing ENTER.

Custom Files Listing

INFO.LSP

```
; INFO.LSP: Routine to call textual data and show illustration.
(defun c:info (/ ERN ERNINT CMND CMND2 Dummy Dummy2)
     (setq ERN (getstring "\nUse the keyboard to enter the Equi
                                  pment Reference Number (ERN): "))
   (setq ERNINT (atoi ERN))
   (while (or(<  ERNINT 1) (>  ERNINT  26))
       (progn
       (setq ERN (getstring "\nYou must enter an ERN
       corresponding to labels on the POL system.\nPlease
       try again.  ERN?:"))
       (setq ERNINT (atoi ERN))
       )
   )
     (setq CMND (strcat "type c:\\acad\\textfile\\" ERN ".txt"))
   (setq CMND2 (strcat "showpic C:\\CLASS\\pic7.pcx"))
     (command "shell" CMND)
   (setq ERNINT (atoi ern))
     (if (= 0 (rem ERNINT 2))
        (progn
        (setq dummy (getstring "Press ENTER for illustration."))
        (command "shell" CMND2))
     )
   (setq dummy2 (getstring "Press Space Bar to continue."))
      (graphscr)
   (princ)
)
```

HELPER.LSP

```
;HELPER.LSP: Routine to display help text
(defun c:helper (/ dummy)
(command "shell" "type help.txt")
(setq dummy (getstring  "\nPress SpaceBar to continue."))
(graphscr)
(princ)
)
```

POLH2O.LSP

```
; POLH2O.LSP Layer changing routine
(defun c:POLH2O (/      )
(command "layer" "set" "0")
(command "off"    "coast,r-paved,fence,hydro-t,dock-seawall,
                        dock-t,r-paved-t,ma-bldg,mi-bldg")
(command "off"    "text,tank,r-dirt-t,comm-line,r-dirt")
```

```
(command   "freeze"    "coast,r-paved,fence,hydro-t,dock-
                seawall, dock-t,r-paved-t,ma-bldg,mi-bldg")
(command "freeze" "text,tank,r-dirt-t,comm-line,r-dirt" "")
(princ)
)
```

SHOWALL.LSP

```
;SHOWALL.LSP:  Layer restoring routine
(defun c:SHOWAll (/      )
(command "layer" "thaw" "*" "on" "*" "")
(princ)
)
```

START.SCR

```
2
base
redraw
menu custom
setvar cmdecho 0
(load "HELPER")
(load "INFO")
(load "POLH2O")
(load "SHOWALL")
```

CUSTOM.MNU

```
***screen
[ZOOM]
[Birdseye]^L
[Window]^c^c^pZW;
[All]^c^c^pZA;
[Previous]'zoom p
[2X In]^c^c^pZI;
[2X Out]^c^c^pZO;
[PAN]^PPC;
[DATA]^cINFO
[DISPLAY]
[Utils]^cPOLH2O
[All Base]^cSHOWALL
[HELP]^cHELPER
[EXIT]^c(command "quit" "y")
```

AC.BAT

```
@echo off
cls
cd\acad
acad base start
```

EXP.BAT

```
@echo off
c:
cd\
cd class
menu 1stclass
as htrun advisor
```

INSTRUCT

```
#Load#
{call command /c c:\class\reload.bat}
{find instructions #main menu#}
#MAIN MENU#  ,,4,1,77,25 ( MAIN MENU )

        *  `1'ADVISOR INSTRUCTIONS`


        *  `1'HIT-FASST EQUIPMENT INSTRUCTIONS`
           (Hydraulic Integrated Tools -
           Field All-purpose Support Trailer)


        *  `1'PIPELINE REPAIR INSTRUCTIONS`


        *  `1'BASE GRAPHICS AND FACILITIES DATA`


        *  `1'QUIT ADVISOR`




Up and Down arrow to move cursor.  ENTER to select.  ESC
to back up one screen.
```

```
#ADVISOR INSTRUCTIONS#
{find Instructions Instructions}
#INSTRUCTIONS# , ,4,1,77,23 ( INSTRUCTIONS )
```

This Repair Advisor is designed to prepare the user to quickly repair POL pipelines damaged by conventional bomb blasts. It has three sections:

1) EQUIPMENT INSTRUCTIONS: This section provides operating instructions for the equipment in the Hydraulic Integrated Tools - Field All-purpose Support SysTem (HIT-FASST).

2) PIPELINE REPAIR INSTRUCTIONS: This section describes the procedures used to quickly repair bomb-damaged fuel lines. Illustrations are used to help clarify the instructions.

3) BASE GRAPHICS AND FACILITIES DATA: This section provides various drawings of the base and POL facilities data.

Proceed to * `1'Page 2`.

#Page 2# ,,4,1,77,23 (INSTRUCTIONS, Page 2)

Use the arrow keys to move the cursor to the highlighted menu items. Then, press ENTER to select that item. Press ESC to back up one screen.

OR

Use the mouse to move the cursor to the highlighted menu items (marked with the symbol *). Click the Left mouse button to select an item. Click the Right mouse button to back up one screen. Clicking both mouse buttons at the same time ends the advising session.

Return to * `1'Main Menu`

#HIT-FASST EQUIPMENT INSTRUCTIONS# ,,4,1,77,23
{Find Eqplist #EQUIPMENT MENU#}
#PIPELINE REPAIR INSTRUCTIONS# ,,4,1,77,23
{Find Repair_Instructions #'BEFORE YOU BEGIN' INSTRUCTIONS#}

#BASE GRAPHICS AND FACILITIES DATA# ,,4,1,77,23
{Find graphics #GRAPHICS MENU#}
#QUIT ADVISOR# ,,4,1,77,23
{Find * #DOUBLE CHECK#}

```
#DOUBLE CHECK# ,,4,1,77,23 ( DOUBLE CHECK )

               Are you sure you want to quit?

                * `1'QUIT`

                * `1'RETURN TO START OF PROGRAM`

#RETURN TO START OF PROGRAM#
{home}
#QUIT#
{Return}
```

EQPLIST

```
     #EQUIPMENT MENU# ,,4,1,77,23 ( HIT-FASST EQUIPMENT LIST )

Hydraulic Equipment (Instructions Available)

 * `1'Power Source`              * `1'Water Pump`
 * `1'Air Compressor`            * `1'Welder`
 * `1'Pipe Cutter`               * `1'Digger`
 * `1'Power Brush Cleaner`

Special Equipment (Instructions Available)

 * `1'Pipe Locator`              * `1'4 Wheel Manual Pipe Cutter`
 * `1'Gas Detector`              * `1'Air Hose Filter/Oiler`
 * `1'Hot Tapper`                * `1'Aqueous Film Forming Foam`
 * `1'Heat Shrink Wrap`          * `1'Pump for Inflatable Seal`
 * `1'Polymer Wrap`            >>* `1'Inflatable Seals`
 * `1'Air Bags`                  * `1'Bonding Wire with Clamps`
 * `1'Pipe Coating Remover`      * `1'Oxygen Meter/Vapor Indicator`
 * `1'Grounding Cable & Clamps`  * `1'Conductivity Meter`

           Proceed to  * `1'Equipment List Page 2`.

#Equipment  List  Page 2# ,,4,1,77,23 (  HIT-FASST  EQUIPMENT
                                              LIST, Page 2 )

Auxiliary Equipment

Circular Saw         Non-spark Sledge       5-Gallon Water Supply
Pliers Set           Non-spark Pry Bar      Open End Wrench Set
Socket Set           Non-spark Brushes      Coarse Wood Rasp
Hex Key Set          Non-spark Shovels      Files with Handle
```

```
Pipe Wrench Set     Utility Pails         Pipe Repair Stand
Screwdriver Set     Portable Lights       Metal Cutting Shears
Ratchet Handles     Nylon Chokers         Explosion-proof Flashlight
Kneeling Mats       Gasket Lubricant      Fire Extinguishers
Saw Blades          Hard Hats             Neoprene Gloves/Boots
Blade Lubricant     Cloth Towels          Ear/Eye Protection
Sandpaper           One-Ton Hand Winch    Diameter Tape Rule
Fire Blankets       Plastic Foil Rolls    Air Pump and Fan
Air Hood            10' AL pipe sections  50' Flexible hose

                    Back up to * `1'previous list`
                    or * `1'return to Main Menu...`
#Previous list#
{Find Eqplist #Equipment Menu#}
#Inflatable Seals# ,,4,1,77,23 ( Inflatable Seals )

Inflatable Seals are special high strength couplers used
for connecting two pipes together.  Instructions for using the
seals are as follows:

  1) Select an inflatable seal that has an I.D. 1/4"  larger
     than the O.D. of the pipes to be joined.
  2) Place a seal on each end the repair pipe.
  3) Slide a retaining shell over each seal.
  4) Hold the repair pipe between the two severed pipe ends.
  5) Slide each seal halfway over the pipe end to be joined.
  6) Insert an inflation valve into the seal thru the
     opening in the retaining shell.
  7) Pressurize the seal with water to 100 psi.  Make sure
     that all of the air is bled out of the seal.
  8) Pressurize the system to normal operating pressure.

               Return to HIT-FASST * `1'Equipment Menu`

#Return to Main Menu...#
{home}
#Power Source# ,,4,1,77,23 ( Hydraulic Power Source )
#Water Pump# ,,4,1,77,23 ( Hydraulic Water Pump )
#Air Compressor# ,,4,1,77,23 ( Hydraulic Air Compressor )
#Welder# ,,4,1,77,23 ( Hydraulic Welder )
#Pipe Cutter# ,,4,1,77,23 ( Hydraulic Pipe Cutter )
#Digger# ,,4,1,77,23 ( Hydraulic Digger )
#Power Brush Cleaner# ,,4,1,77,23 ( Hydraulic Power Brush
                                                    Cleaner )
#Hot Tapper# ,,4,1,77,23 ( Hot Tapper )
#4 Wheel Manual Pipe Cutter# ,,4,1,77,23 ( 4 Wheel Manual Pipe
                                                     Cutter )
#Heat Shrink Wrap# ,,4,1,77,23 ( Heat Shrink Wrap )
#Pipe Locator# ,,4,1,77,23 ( Pipe Locator )
```

#Air Hose Filter/Oiler#,,4,1,77,23 (Air Hose Filter and Oiler Assembly)
#Aqueous Film Forming Foam# ,,4,1,77,23(Aqueous Film Forming Foam)
#Polymer Wrap# ,,4,1,77,23 (Polymer Wrap)
#Inflatable Seals# ,,4,1,77,23 (Inflatable Seals)
#Air Bags# ,,4,1,77,23 (Air Bags)
#Bonding Wire with Clamps# ,,4,1,77,23 (Bonding Wire with Clamps)
#Pipe Coating Remover# ,,4,1,77,23 (Pipe Coating Remover)
#Oxygen Meter/Vapor Indicator# ,,4,1,77,23 (Oxygen Meter/ Vapor Indicator)
#Pump for Inflatable Seal# ,,4,1,77,23 (Pump for Inflatable Seal)
#Gas Detector# ,,4,1,77,23 (Gas Detector)
#Grounding Cable & Clamps# ,,4,1,77,23 (Grounding Wire & Clamps)
#Conductivity Meter# ,,4,1,77,23 (Conductivity Meter)

Operating instructions

for this equipment

are currently unavailable.

Press ESC (or click the Right mouse button) to back up.

REPAIR

#'BEFORE YOU BEGIN' INSTRUCTIONS# ,,4,1,77,23 (IMPORTANT PRECAUTIONS!)

Before you begin any repair operations, there are important preliminary steps that must be taken.

1) Close the shut-off valves immediately upstream and downstream of the damaged pipe section.
2) Disconnect the cathodic corrosion protection, if any, from the pipeline. This reduces the risk of stray sparks igniting a fire.

Press ENTER to * `1'continue`.

#continue#
{Find Repair_i #Fuel Facilities Repair Instructions#}
#Fuel Facilities Repair Instructions# ,,4,1,77,23
(REDUNDANT PIPELINES?)

If there is a redundant pipeline path for the fuel to flow through to avoid the damaged section, the quickest solution to the problem is to reroute the fuel flow. Adjust the appropriate valves to redirect the flow of fuel around the damaged portion.

Select one...

* `1'Continue...`

* `1'Consult Base Graphics`

#Continue...#
{Find Repair_I #Fuel Facilities Repair Menu#}
#Consult Base Graphics#
{Find Graphics #Graphics Menu#}
#FUEL FACILITIES REPAIR MENU# ,,4,1,77,23 (PIPELINE REPAIR INSTRUCTIONS MENU)

* `1'IN-CRATER-FIRE FIGHTING`

* `1'IN-CRATER PIPELINE REPAIR`

* `1'CRATER BYPASS`

* `1'Return to Main Menu...`

Note: If at any time you need specific instructions on how to use a particular piece of equipment, return to the Main Menu and select HIT-FASST EQUIPMENT INSTRUCTIONS. Complete operating instructions are available for all special equipment.

#IN-CRATER-FIRE FIGHTING# ,,4,1,77,23 (IN-CRATER FIRE-FIGHTING INSTRUCTIONS)

In instances where a fuel-filled, burning crater is encountered, there are two options that can be taken.

Select one...

* `1'Extinguish the fire and perform the In-Crater Repair.`

* `1'Bypass the crater.`

* `1'Return to Pipeline Repair Instructions Menu.`

#Bypass the crater.#
{Find Repair_I #Crater Bypass#}
#Extinguish the fire and perform the in-crater repair.#
{Find Repair_I #Fire Extinguishing#}
#Fire Extinguishing# ,,4,1,77,23 (IN-CRATER FIREFIGHTING INSTRUCTIONS)

One method of extinguishing a flaming crater is to have the burning fuel flow through a long pipe. This causes the fuel to extinguish itself. This technique can be accomplished using the following procedure.

In addition to the HIT-FASST, the following equipment will be needed:

Backhoe or Digger

1) Obtain a pipe section 20 ft. long or longer (4" - 10" diameter). If a 20 ft. section is not available, use mechanical couplers to join smaller pipe sections together.
2) Use a backhoe to dig a trench that begins two feet away from the edge of the flaming crater and extends radially outward. The trench should be at least as deep as the crater, and get slightly deeper as it extends away from the flame. It is important that the trench be dug in a direction downwind from the flaming crater to prevent another fire from igniting.

Proceed to *`1'Page 2`.

#Page 2# ,,4,1,77,23 (FIREFIGHTING INSTRUCTIONS, Page 2)

3) Dig another crater at the end of the trench to act as a reservoir for the fuel after it flows through the trench.
4) Place the pipe section in the trench, close to the lip of the crater.
5) Break through the final lip of the flaming crater and allow the fuel to flow through the pipe section. By the time the fuel reaches the end of the pipe, the flame should be extinguished.

Select One...
    * `1'View Illustration 2`
    Back up to * `1'Fire Extinguishing` Instructions, Page 1
    * `1'Return to Pipeline Repair Instructions Menu...`

#View Illustration 2#
{call showpic pic2.pcx}
{call showpic pic3.pcx}
{call command /c c:\class\reload.bat}
#Crater Bypass# ,,4,1,77,23 (CRATER BYPASS INSTRUCTIONS)

The simplest way to repair a damaged fuel line is to bypass the damaged section altogether by using pre-positioned bypass valves and redundant pipelines.

1 Using the fuel system diagrams in the Base Graphics portion of the advisor, locate and close the shut-off valves immediately upstream and downstream from the damaged pipe.

2 Locate the pre-positioned redundant pipeline (if any) and use the shut-off valves to redirect the fuel flow to avoid the damaged pipe section.

Return to * `1'Fuel Facilities Repair Menu`.
#In-Crater Pipeline Repair# ,,4,1,77,23 (IN-CRATER REPAIR INSTRUCTIONS)

The following is an outline of the steps that must be taken when performing an In-Crater Repair. Move the cursor to each one and press ENTER for further instructions.

```
>>> 1) * `1'Position the HIT-FASST` >>> 2) * `1'On-site preparation
    3) * `1'Locate pipeline`            4) * `1'Excavate`
    5) * `1'Apply vapor retardants`     6) * `1'Electrically ground
                                                 pipe ends`
    7) Perform repair
       a) * `1'Small holes`
  >>>  b) * `1'Broken/crushed pipe`     8) * `1'Leak Test`
    9) * `1'Document repairs`
```

Return to * `1'Fuel Facilities Repair Menu`.

#On-Site Preparations# ,,4,1,77,23 (ON-SITE PREPARATIONS)

1) * `1'Measure %LEL`(Lower Explosive Limit).
2) * `1'Determine excavation needs`, ie. vapor barrier, expose pipe ends.
3) * `1'Start power sources` as necessary.
4) * `1'Set up lights` (if needed).
5) * `1'Pump out liquid fuel` (as required).
6) * `1'Install vapor exhauster` (as required).
7) * `1'Lay out tools` and materials at crater edge.
8) * `1'Put on Personal Protective Equipment` (as required).
9) * `1'Verify %LEL` is below 40% before entry, and that hoods are in place if %LEL is above 4%.

Return to * `1'In-Crater Pipeline Repair` Outline.

#Position the HIT-FASST# ,,4,1,77,23 (POSITIONING THE HIT-FASST)

When positioning the HIT-FASST, it is important that the trailer be parked 35-50 ft from the crater in a direction that is neither upwind, nor downwind from the crater. This will minimize the chances of a stray spark igniting a fire while permitting the operation of the power tools in the crater.

Select one...

* `1'View Illustration 4`

Return to * `1'In-Crater Pipeline Repair` Outline.

#View Illustration 4#
{call showpic pic4.pcx}
{call command /c c:\class\reload.bat}
#Set up lights# ,,4,1,77,23 (SET UP LIGHTS)

#Measure %LEL# ,,4,1,77,23 (MEASURE % LEL)
#Determine Excavation Needs# ,,4,1,77,23 (DETERMINE EXCAVATION NEEDS)
#Start Power Sources# ,,4,1,77,23 (START POWER SOURCES)
#Locate pipeline# ,,4,1,77,23 (LOCATE PIPELINE)
#Pump out liquid fuel# ,,4,1,77,23 (PUMP OUT FUEL)
#Install Vapor Exhauster# ,,4,1,77,23 (INSTALL VAPOR EXHAUSTER)
#Lay Out Tools# ,,4,1,77,23 (LAY OUT TOOLS)
#Put On Personal Protective Equipment# ,,4,1,77,23 (PUT ON PPE)
#Verify %LEL# ,,4,1,77,23 (VERIFY %LEL)
#Excavate# ,,4,1,77,23 (EXCAVATE)
#Apply vapor retardants# ,,4,1,77,23 (VAPOR RETARDANTS)
#Electrically ground pipe ends# ,,4,1,77,23 (GROUNDING THE PIPE ENDS)
#Small Holes# ,,4,1,77,23 (SMALL HOLES)
#Leak Test# ,,4,1,77,23 (LEAK TEST)
#Document Repairs# ,,4,1,77,23 (DOCUMENT REPAIRS)

Detailed instructions

for this procedure

are currently unavailable.

Press ESC (or click the Right mouse button) to back up.
#Broken/crushed Pipe# ,,4,1,77,23 (INFLATABLE SEAL REPAIR)

When the pipeline has been severely damaged, follow the repair instructions below.

1) Insure that enough excavation was performed to expose nearly in-round and in-line pipe.
2) Electrically ground both sides of the damaged pipe section.
2) Cut off damaged pipe ends using hydraulic pipe cutter.
3) Using the manual coating remover, strip off 8" of the pipe coating from each end of pipe.
4) Cut a piece of repair pipe to fit between the cut off pipe ends. There should be no more than 1/4" gap on either side when the repair pipe is in place.
5) Use the inflatable seals to join the replacement pipe section to the severed pipe ends.

Select one...

View * `1'Illustration 5`.
Return to * `1'In-Crater Pipeline Repair` Outline.

```
#Illustration 5#
{call showpic pic5.pcx}
{call showpic pic6.pcx}
{call command /c c:\class\reload.bat}



#Return to Pipeline Repair Instructions Menu...#
{Find Repair_I #Fuel Facilities Repair Menu#}
#Return to MAIN MENU...# ,,4,1,77,23
{home}
```

GRAPHICS

```
#GRAPHICS  MENU# ,,4,1,77,23 ( BASE GRAPHICS AND  FACILITIES
 MENU )


Select one...

            Display the * `1'PLAN VIEW` of NAS Adak.

            * `1'Return to Main Menu...`


#PLAN VIEW# ,,4,1,77,23 ( INSTRUCTIONS? )

      Do you want instructions for the graphics section?

Select one...

                              * `1'Yes`

                              * `1'No`

#Yes#
{Find graphics #instructions#}
#No#
{call command /c c:\class\menu off}
{call command /c c:AC}
{call command /c c:\class\reload.bat}
{home}
#Instructions# ,,4,1,77,23 ( GRAPHICS INSTRUCTIONS )
```

Once activated, it takes a few minutes for the computer to generate the drawing of the base. When the prompt "Command:" is displayed at the bottom of the screen, you may select any of the various commands from the graphics menu.

Proceed to * `1'Page 2`.

#Page 2# ,,4,1,77,23 (GRAPHICS INSTRUCTIONS, Page 2)

The graphics menu is located along the right side of the screen. To select an item from the menu, move the mouse so that the cross-hairs rest on the item and then press the left mouse button once.

Proceed to * `1'Page 3`.

#Page 3# ,,4,1,77,23 (GRAPHICS INSTRUCTIONS, Page 2)

The graphics menu gives you the following options:

Zooming in on or out of the drawing several different ways,
Panning across the drawing,
Calling up textual data on various components of the fuel system,
Displaying either the whole base, or just the Fuel Lines, Water Lines and Runways,
Exiting from the graphics section.

Select one...
Proceed to the * `1'Base Graphics`
* `1'Return to Main Menu...`

#Base Graphics#
{Find Graphics #No#}
#Return to MAIN MENU...#
{home}

Appendix B

DAMAGE ASSESSMENT AND RECOVERY MANAGEMENT SYSTEM (DARMS)

TM No. M64-90-07

NCEL Technical Memorandum

Title: DAMAGE ASSESSMENT AND RECOVERY MANAGEMENT SYSTEMS (DARMS)

Author: PATRICK PRONDZINSKI

Date: NOVEMBER 1990

Sponsor: OFFICE OF NAVAL TECHNOLOGY

Program No.: PE 62233N

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043

DISCLAIMER

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial equipment. This report may not be cited for purposes of advertisement.

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INTRODUCTION

The capability to rapidly repair damaged facilities such as runways or fuel lines is of critical importance to the security of the United States. Following a conventional attack on a Naval Base, the U.S. Navy must be capable of rapidly restoring critical facilities needed to continue mission essential operations. The restoration must be accomplished in minimal time frames. A computer based concept known as Damage Assessment and Recovery Management System (DARMS), was conceived to provide an effective communication platform. DARMS assists in restoration efforts that include locating, assessing, and managing the repair of facilities damaged. DARMS also contains information concerning the status of the base and personnel. The Naval Civil Engineering Laboratory (NCEL), in conjunction with the Air Force, has developed a demonstration model of DARMS.

The DARMS concept operates on a Tektronix computer workstation and provides the recovery officer with comprehensive information needed to quickly locate and assess damage incurred to essential base facilities. It is a "real time" graphic information system based on a two-way communication computer system. The Damage Assessment Teams (DATs) physically survey the base. Damage data, such as coordinates or damage extent, is entered into a hand held computer, and digitally burst in real time, from the DATs to a central computer workstation known as the Survivable Recovery Center (SRC) [1]. A two dimensional graphic representation of base facilities, as well as the digitally burst damage data (represented as icons), is displayed on the workstation monitor. With a comprehensive knowledge of facilities, damage assessment (provided via DARMS), and operational requirements, the recovery officer can quickly prioritize repair work and safely direct the repair crews.

The current procedure for damage identification and assessment is for DATs to physically survey base damage and relay information via voice transmission or hand carrying it to a designated location where information is collated for recovery planning. During the air base operability exercises held in Spagdalem, Germany (Salty Demo) it was demonstrated that these methods of damage assessment and identification were unacceptable.

Identification, assessment, and subsequent recovery of runways or fuel facilities, must be completed within four hours. Development of DARMS assisted in determining the feasibility of automating the transfer of base recovery information from DATs to the SRC in meeting the four hour requirement.

BACKGROUND

NCEL developed an integrated Naval Damage Assessment and Control System to improve the recovery capability of Naval bases after an enemy attack. To effectively utilize existing and/or developing technologies pertinent to damage assessment and recovery, NCEL worked closely with the Air Base Operability (ABO) Office at Elgin Air Force Base. The Survivable, Base Recovery After Attack (BRAAT), Computer System (SBCS) program being developed at Elgin AFB offered the Navy the opportunity to use a Graphic Information System (GIS) for assessing base damage. NCEL used the previous SBCS computer program core to demonstrate the DARMS concept for Navy unique facilities.

Naval procurement of DARMS began in September, 1986. The government procurement specification for the DARMS system is included in the NDACS YQ 86-1 specification. The original contract began in September, 1986 with SofTech, Inc. Final demonstration system acceptance of DARMS was on September 7, 1989 [3].

OBJECTIVE

The objective of DARMS is to determine the feasibility of using a computer system to fill a technological gap as a damage assessment and control tool in the base recovery environment.

DISCUSSION

The DARMS software was written in "C" computer language and runs on a single Tektronix 4324 computer using the UTEK operating system. It is anticipated that the Tektronix work station will be operated in the SRC under direct supervision of the base commander. The communications link between the base commander and DATs is provided by a Telxon RFC-30 base station hard wired to the Tektronix computer and via radio frequency link to a Telxon Portable Tele-transaction Computer (PTC). The PTC base station and computer operate on a dedicated Navy radio frequency of 409.8687 MHz, have an antenna power output of two watts, and can operate at temperatures from 32 to 120 degrees Fahrenheit. The first version of the DARMS and SBCS software was developed by SofTech, Inc., of Alexandria, Virginia.

DAT team members utilize the PTC hand held computers to digitally burst damage and work progress information to the SRC. The information is then used to update the DARMS main computer database via the communication base station. The base commanders can then send tasking information via mail to DAT members and via computer base station and hand held computers to base recovery personnel. A diagram of the data flow and transmission path is illustrated in Figure 1.

Naval Air Station (NAS) Adak, Alaska, was selected for the DARMS geographic and data base information system. Adak is considered a fixed forward base which contains facilities and assets to provide critical functions for the conduct of Naval warfare [4]. The Graphic Engineering and Mapping System (GEMS) was also implemented at Adak. This system provided instant and detailed, base layout information necessary for DARMS. The base map of NAS Adak used in DARMS is included in Figure 2. The graphics segment of the computer software provides the SRC operator the capability of activating facilities overlays on the base map displayed on the computer screen. This capability allows the computer operator to view a specific area of interest or the entire facility at one time. Facilities overlays include buildings, roads, runways, taxiways, coast lines, water lines, fuel lines, and base grid. The operator of the DARMS main computer workstation may also pan and zoom the base layout displayed on the computer screen. Panning and zooming can assist the the computer operator in isolating specific segments of the base that are of particular interest.

The graphic segment of the DARMS main computer workstation also includes icons on the base map. Icons provide visual keys to the location of unexploded ordinance (UXO), holes of entry (HOE), mines, damaged buildings, chemicals, damaged fuel lines/water lines, craters, and spalls. These icons may also be activated at the preference of the computer operator. Icon locations are extracted from damage information sent by DATs to the DARMS main computer.

The data base segment of DARMS includes report, detail, and tasking report screens. Report and detail screens consist of a tabular representation of data extracted from the information sent to the main computer by DAT members. Tasking screens include information from the base commander on the recovery teams which are responsible for specific facilities. The report, detail, and tasking screens that are included in DARMS include chemical reports, communications, Explosive Ordinance Disposal (EOD), EOD tasking, EOD reports, HOE reports, facilities, crater/spall detail, crater/spall tasking, Minimum Operating Strip (MOS), Rapid Runway Repair (RRR), Fiberglass (FRP) mat repairs, RRR Pre-cast Concrete (PCC) repairs, personnel status, weather information, and fuel/water damage. A copy of each of the screens listed are included in Figures 3 through 16.

DARMS also allows screen printing within the program on a color printer. This provides the base commander the ability to print any of the tabular display screens, base map, or tasking assignments, at any time. In the event the radio link between the main computer and the PTCs is lost, hard copies of the tasks can be produced and distributed to the recovery teams.

An extensive DARMS acceptance test program was completed in September, 1989. Test results are included in Reference [3]. An acceptance demonstration was conducted on September 7, 1989 at the Naval Facilities Engineering Command headquarters to attract possible transition sponsors.

Four NCEL personnel were trained during September 1989 by SofTech personnel. Approximately 30 hours of training was required for each individual. Operational instructions for DARMS are included in the software users manual [5].

DARMS operates on a single Tektronix workstation. This limits the use of the main computer station in the SRC to a single user. A local area network (LAN) of computers for DARMS in the SRC would allow multiple users of DARMS for tasking and data base management. A LAN would also allow the base commander to tailor the size of DARMS to his particular base specifications.

The current DARMS is not a fully operational damage assessment and control system. Considerable advanced development would be necessary for field use of the system. For example, changes to the data base and base map are very difficult. However, DARMS has demonstrated the concept that a computer system can assist a base commander in damage assessment and recovery after an attack.

In light of the advancement in computer technology over the development of DARMS and SBCS, the Air Force continued the development of SBCS by rewriting the computer software under "X" windows" and using four IBM compatible 80486 personal computers in a LAN. The Navy however, elected not to continue developing DARMS in exploratory development because the concept of computerized damage assessment and control system concept was proven.

The Air Force has continued development of SBCS and plans on a final test and evaluation of the current version at Homestead Air Force Base in Florida during April 1991. The first completed SBCS system is to be installed at an Air Force Base in the Fall of 1991. The current version of SBCS runs on a group of four IBM compatible, 80486 personal computers. The current contractor for SBCS is Sumaria Systems, Inc. of Wakefield, Massachusetts.

Currently, DARMS and SBCS do not permit input of data base information via sensors. The implementation of ground based sensors would enhance the effectiveness of DARMS by providing real time data base information and by protecting DAT members from hostile environments. Sensors could help base personnel determine damage such as crater size, fires, and holes of entry. Ideally, DAT members and the recovery crew would not need to begin recovery procedures until an initial assessment of damage is completed.

CONCLUSIONS

DARMS has demonstrated that a damage assessment and control computer system is feasible. A damage and control system is a required asset in the SRC of all bases before, during, and after an attack. Implementation of a damage and control system will greatly enhance the speed and effectiveness of recovery from an attack.

RECOMMENDATIONS

1. NCEL should monitor the Air Force development of SBCS (version 2). This would allow the Navy to easily use SBCS as a developmental base for future acquisition.

2. Ground and aerial sensor systems should be investigated for future integration with DARMS.

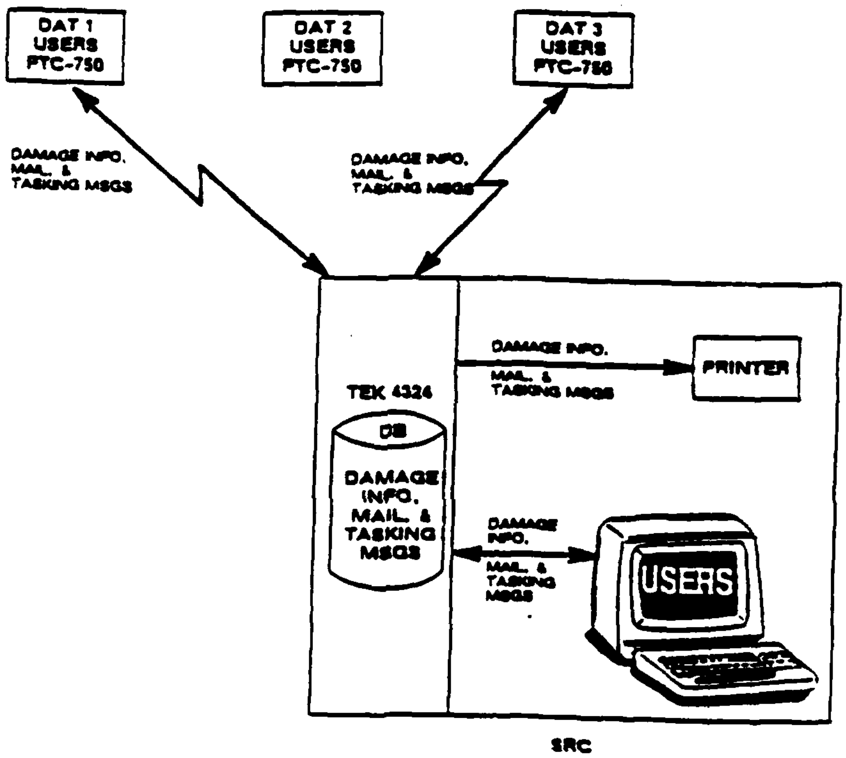
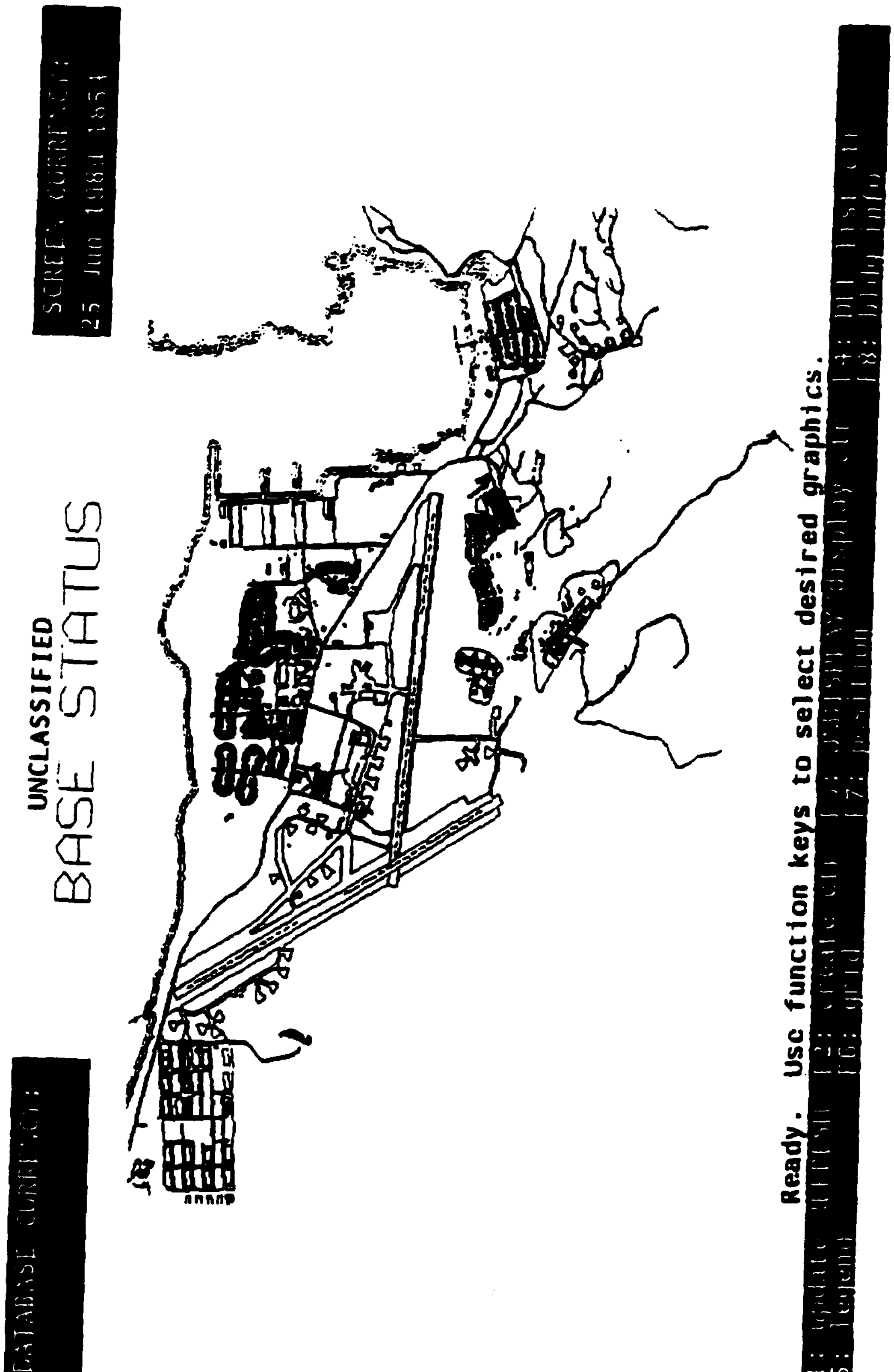


FIGURE 1: DARMS DATA FLOW AND TRANSMISSION PATH



UNCLASSIFIED

FIGURE 2: BASE MAP

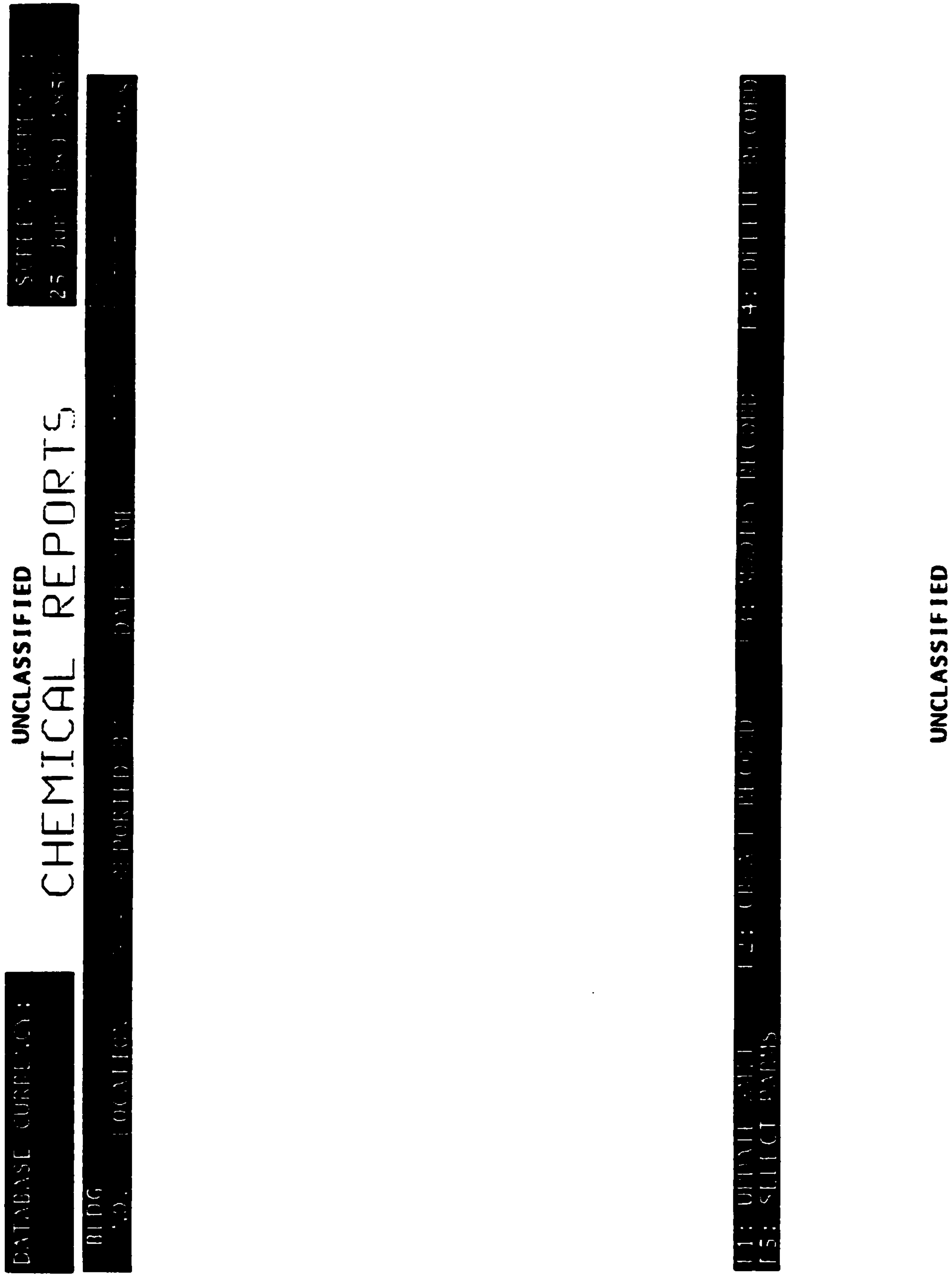
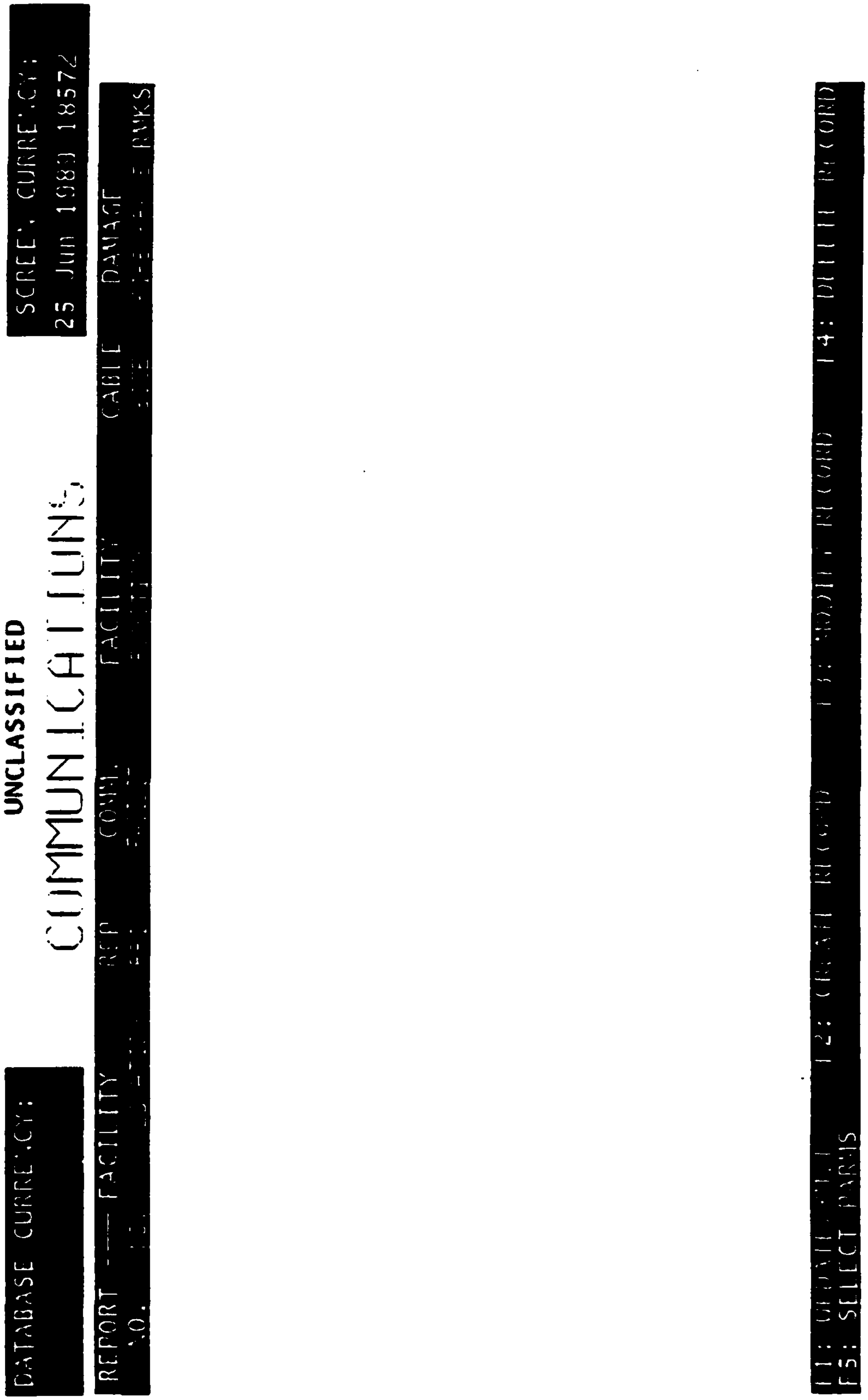


FIGURE 3: CHEMICAL REPORTS SCREEN

UNCLASSIFIED



UNCLASSIFIED

FIGURE 4: COMMUNICATIONS SCREEN

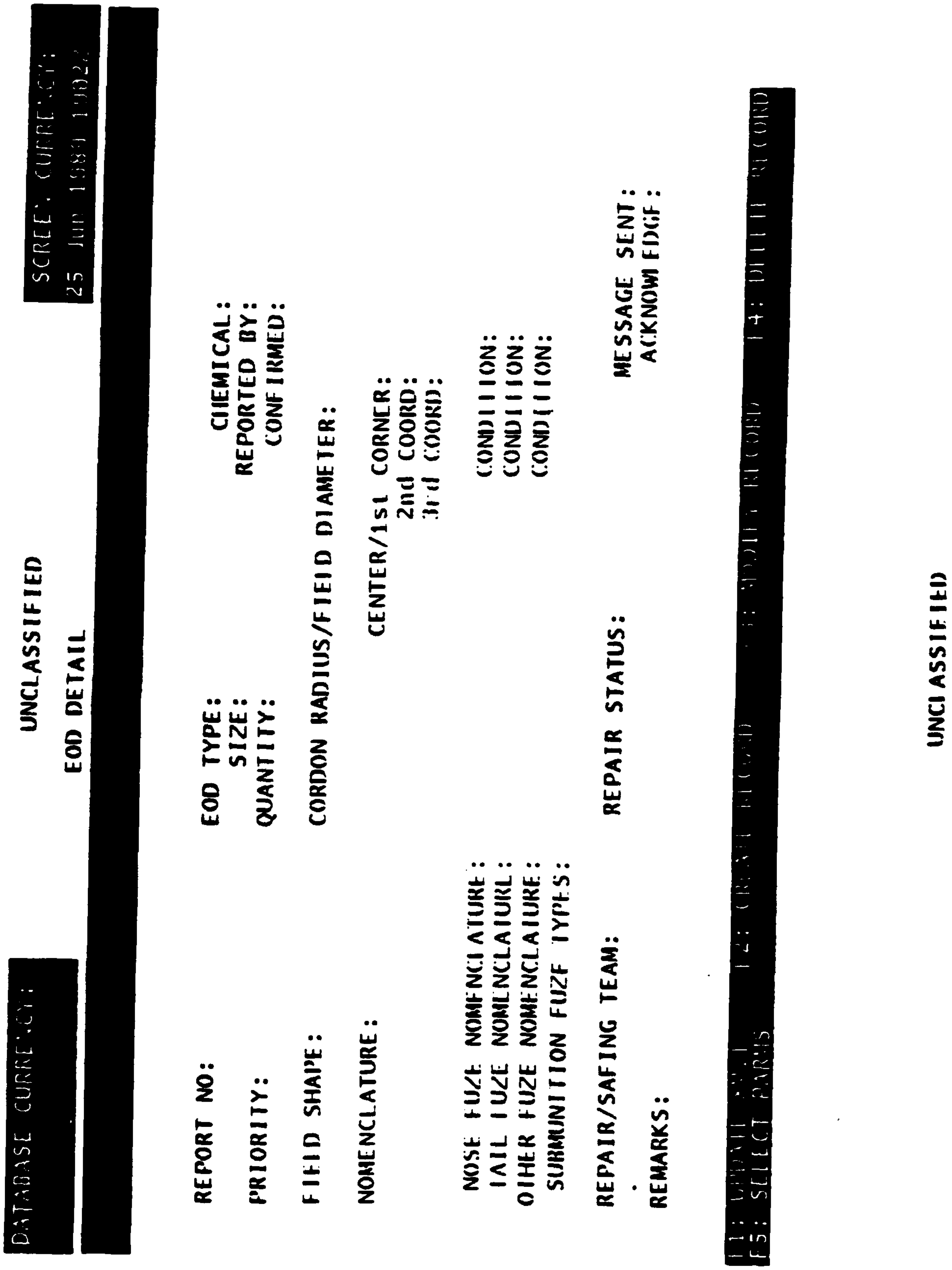


FIGURE 5: EOD DETAIL SCREEN

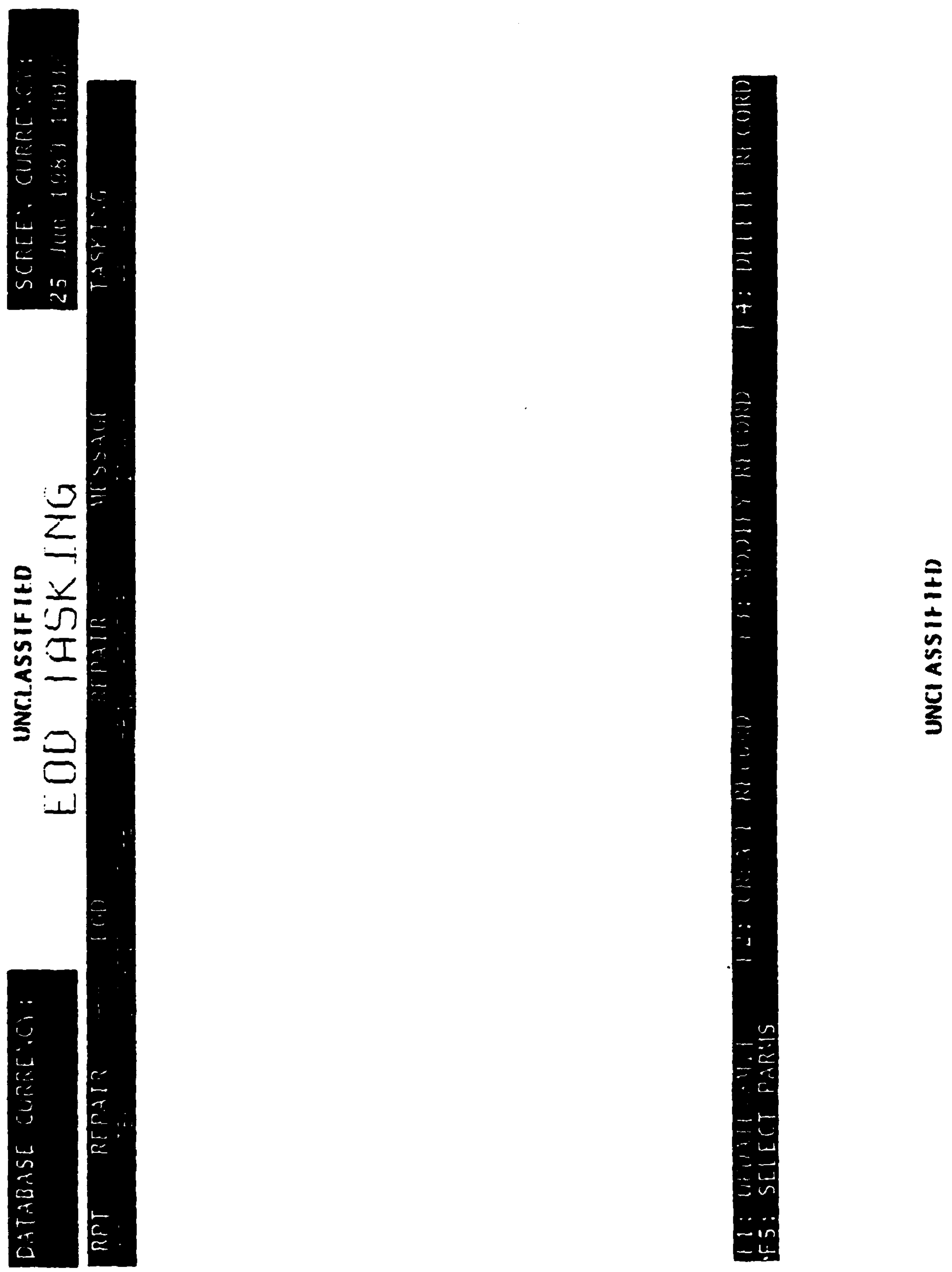


FIGURE 6: EOD TASKING SCREEN

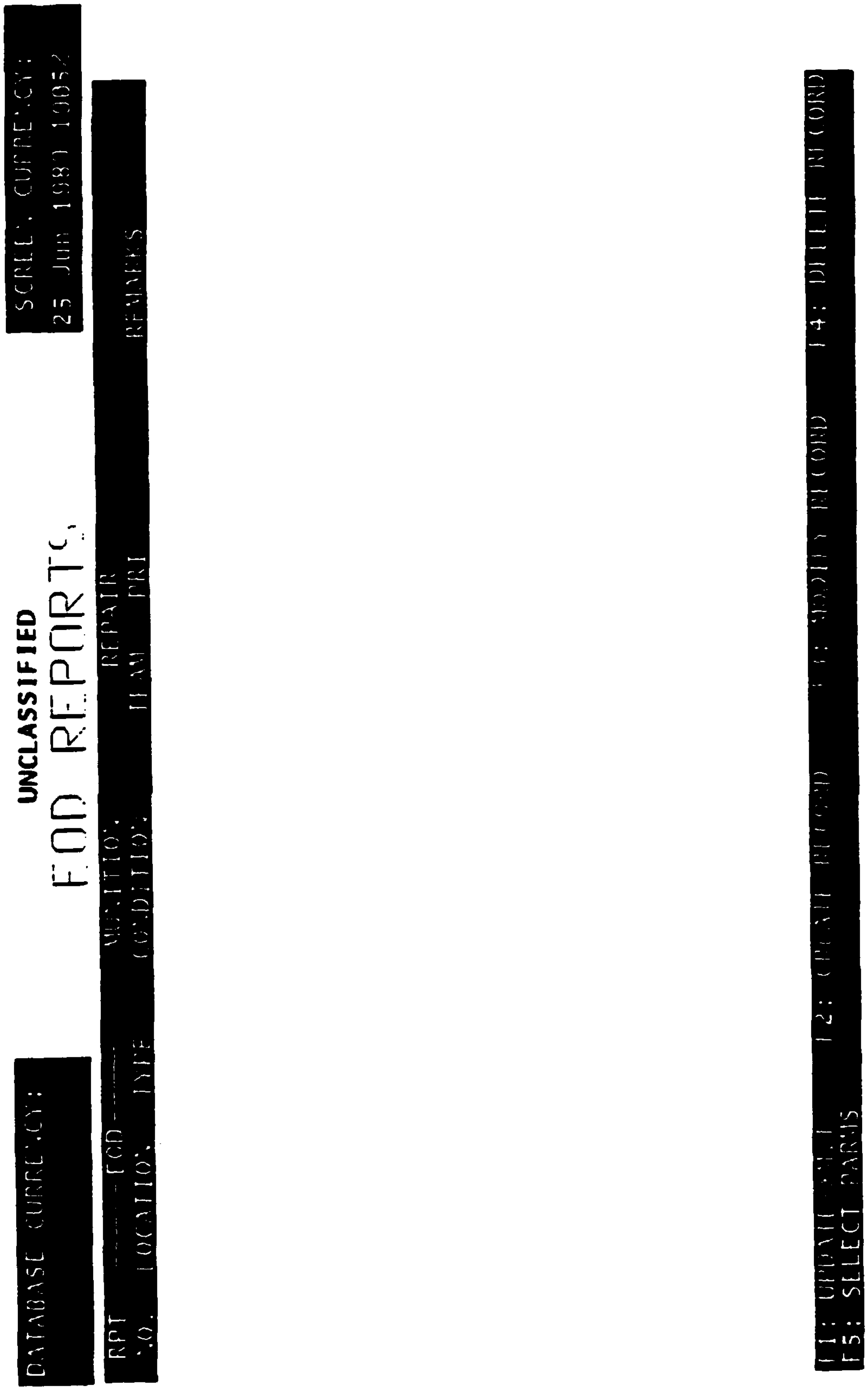


FIGURE 7: EOD REPORTS SCREEN

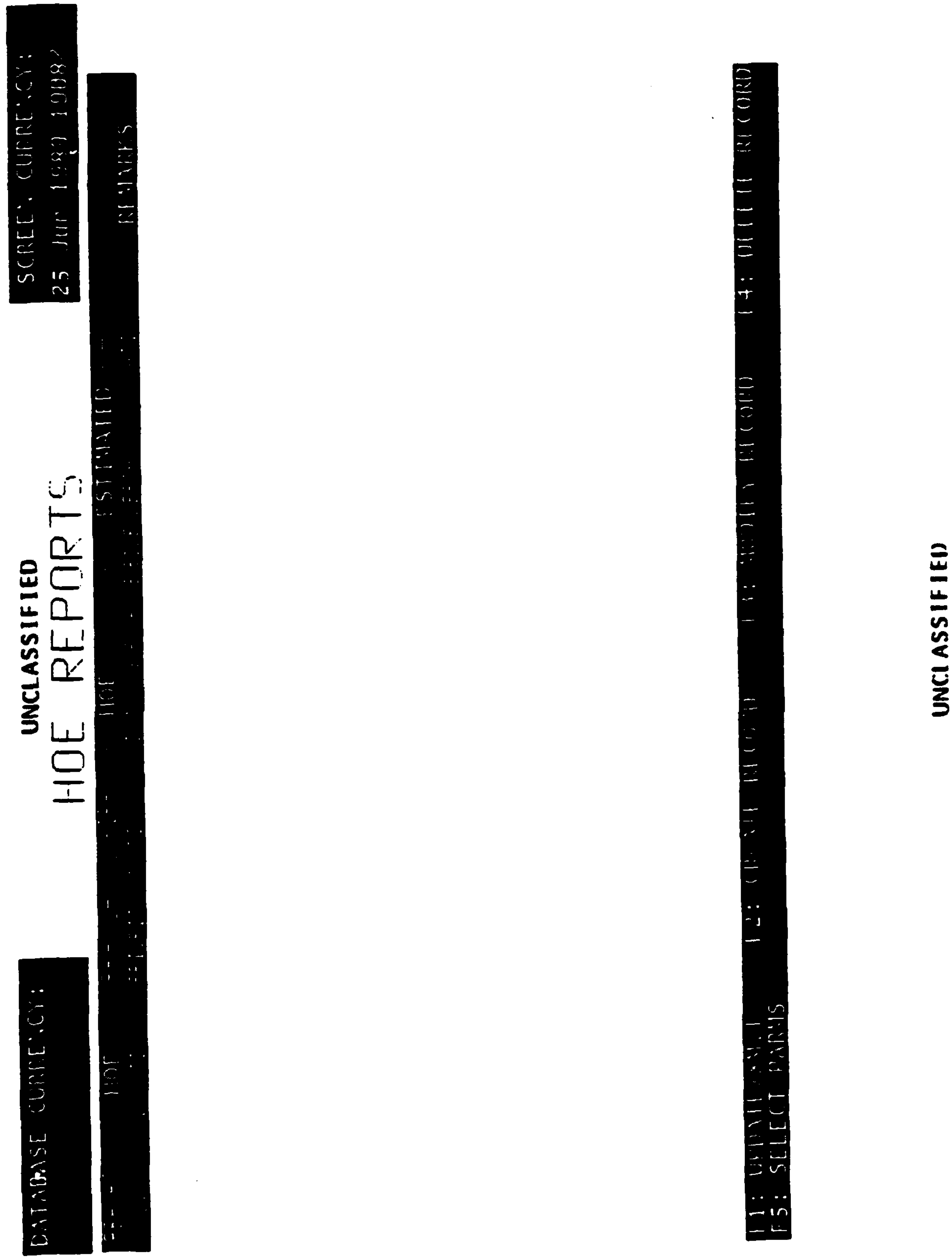
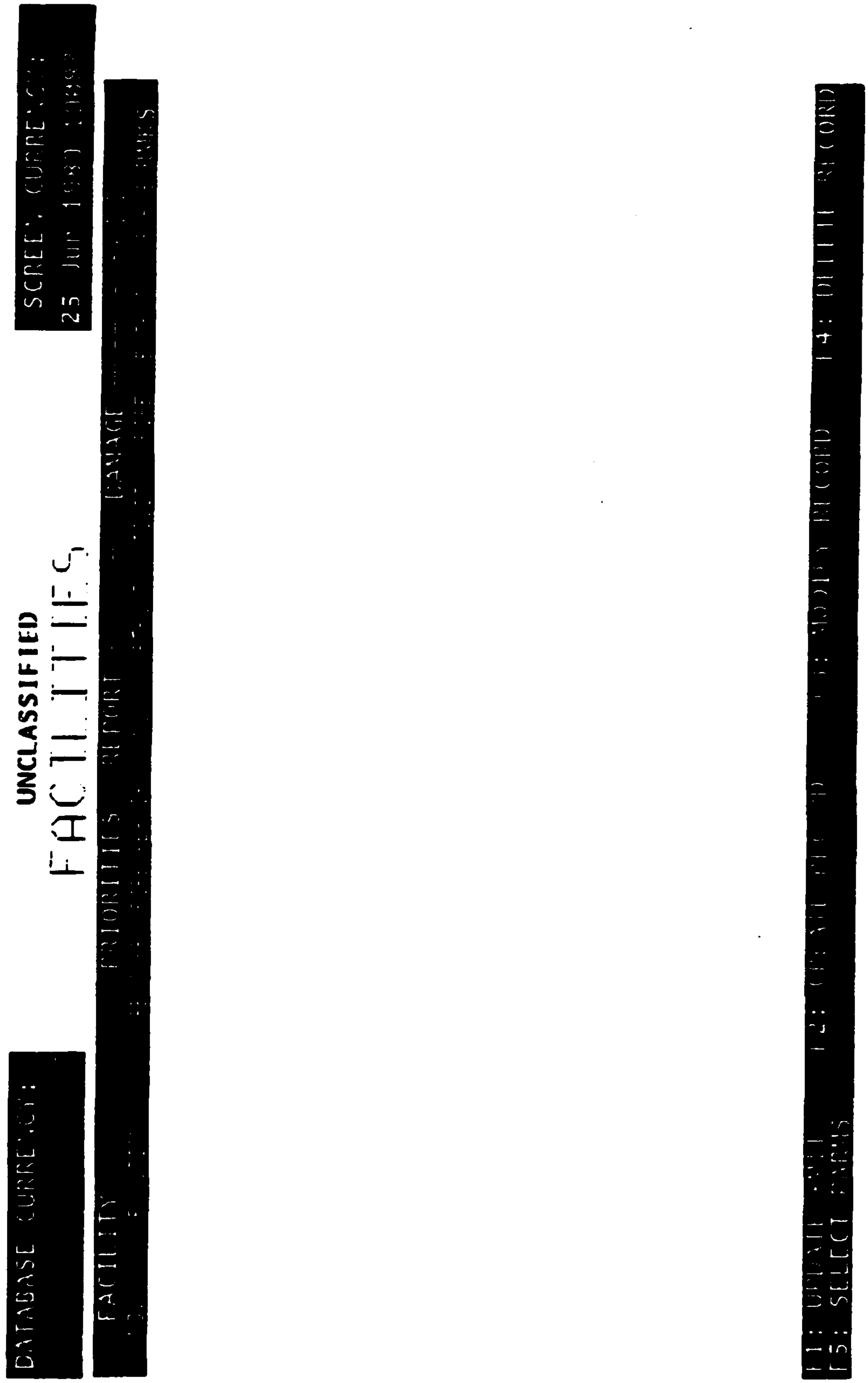


FIGURE 8: HOE REPORTS SCREEN

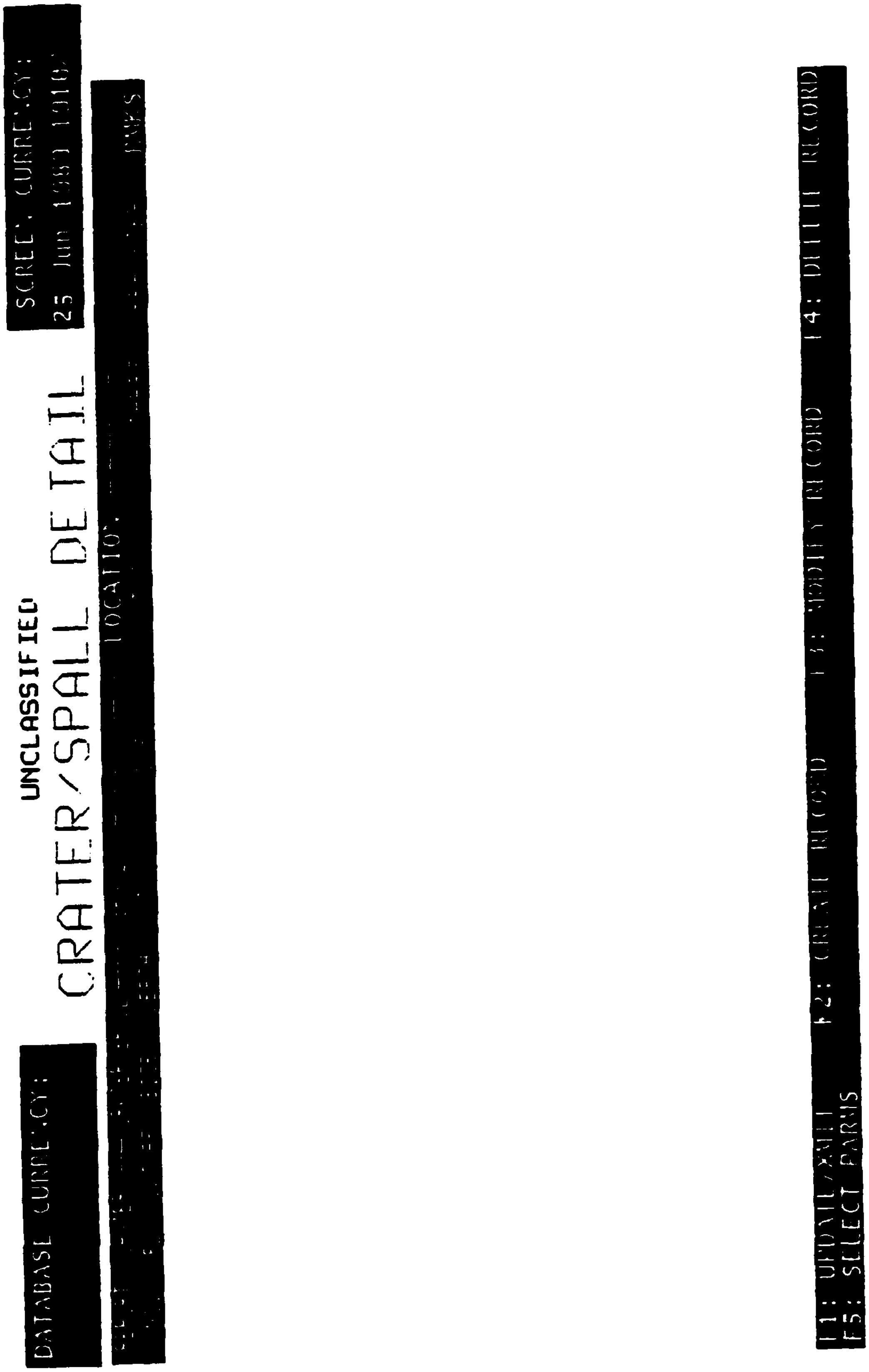
UNCLASSIFIED



UNCLASSIFIED

FIGURE 9: FACILITIES SCREEN

UNCLASSIFIED



UNCLASSIFIED

FIGURE 10: CRATER/SPALL DETAIL SCREEN

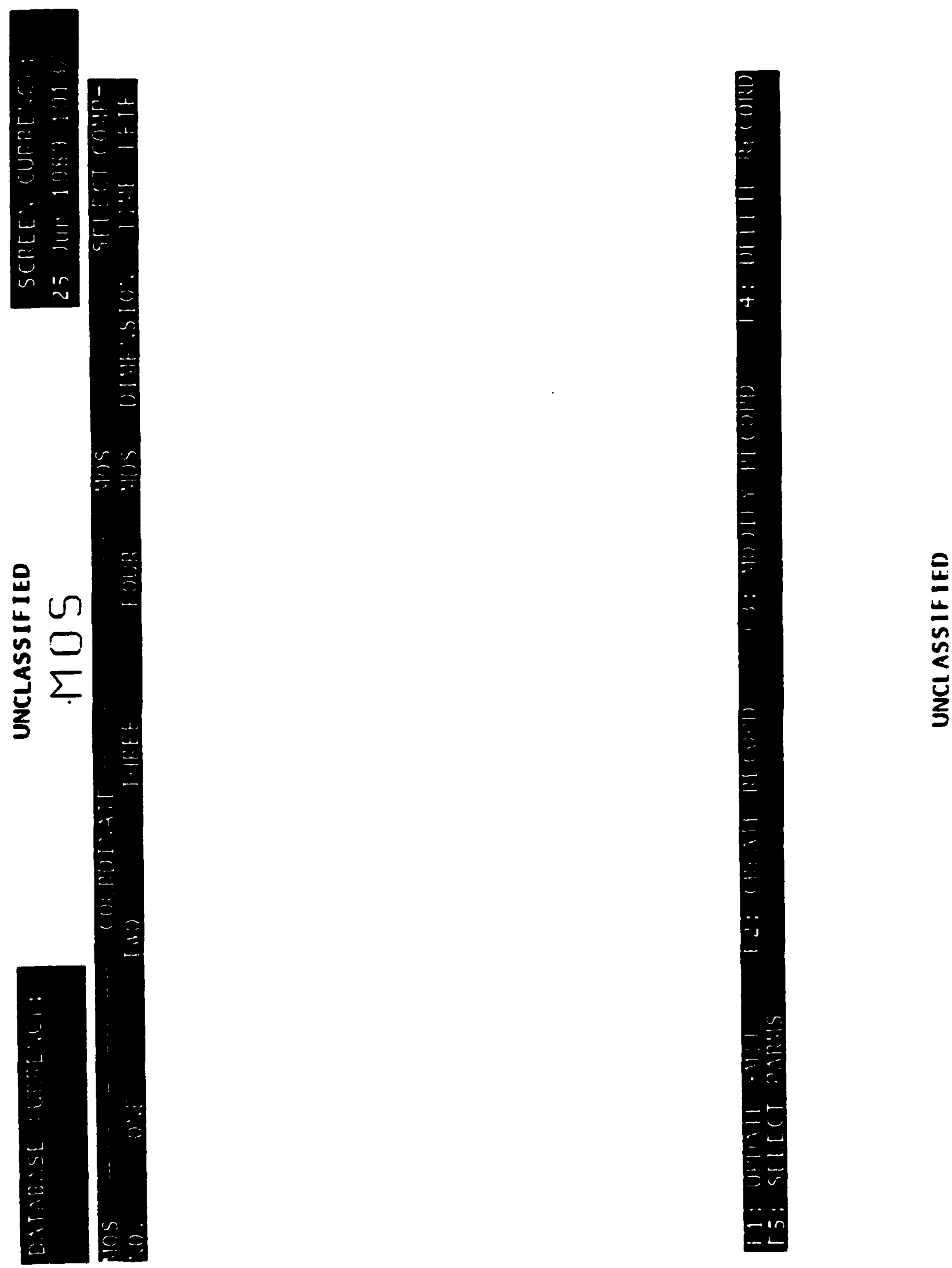


FIGURE 11: MOS SCREEN

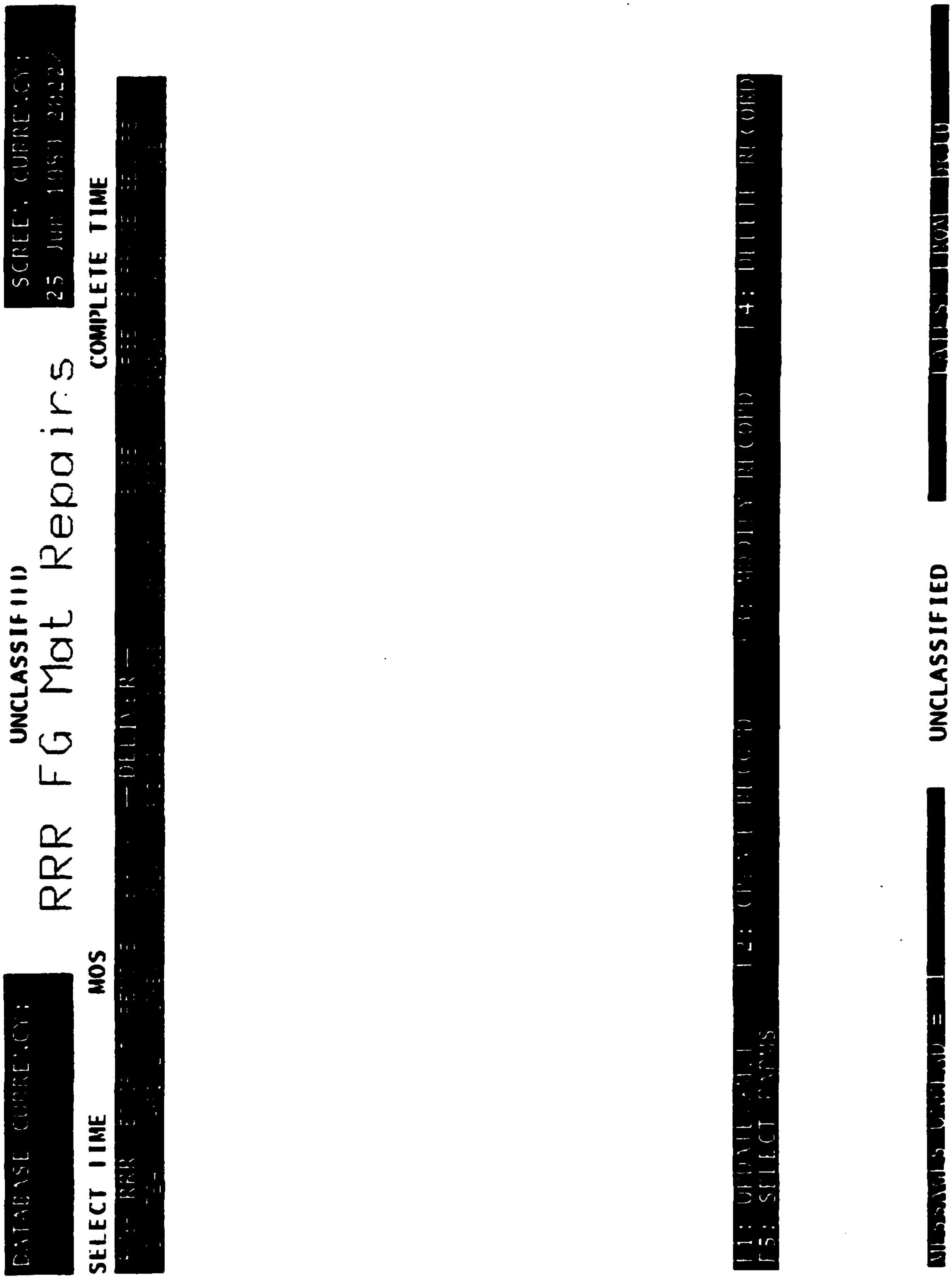


FIGURE 12: RRR FG MAT REPAIRS SCREEN

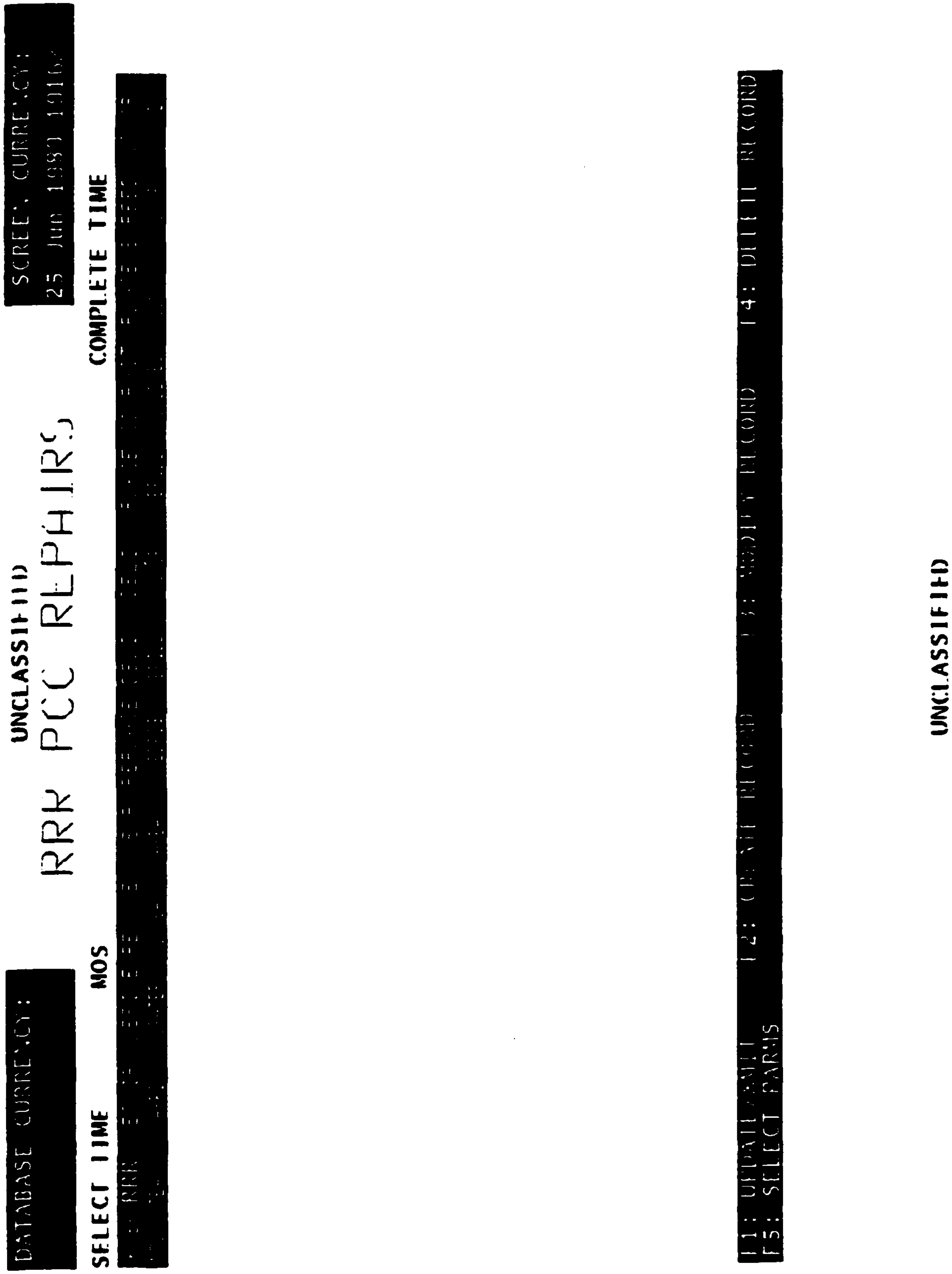


FIGURE 13: RRR PCC REPAIRS SCREEN

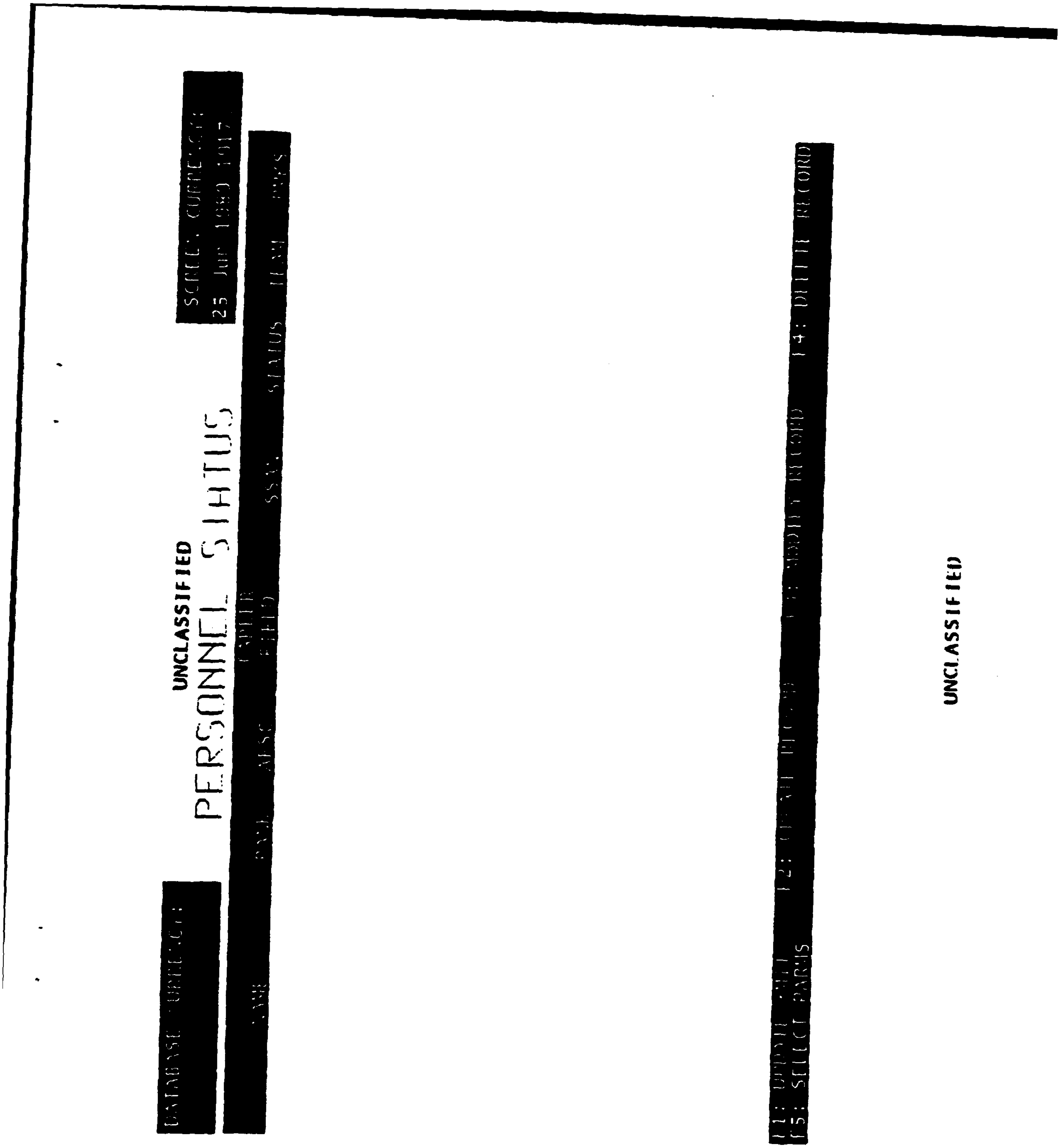


FIGURE 14: PERSONNEL STATUS SCREEN

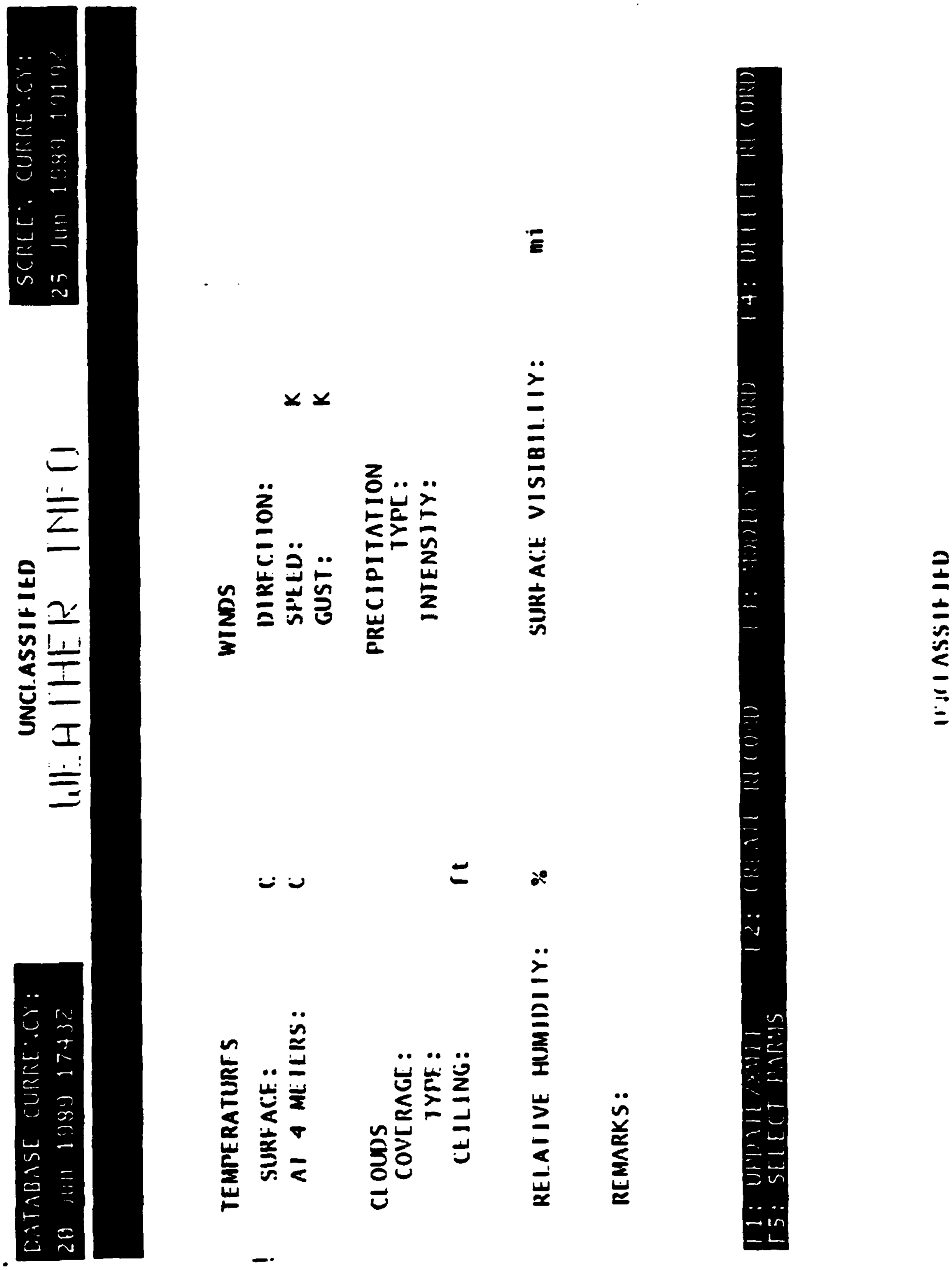


FIGURE 15: WEATHER INFORMATION SCREEN

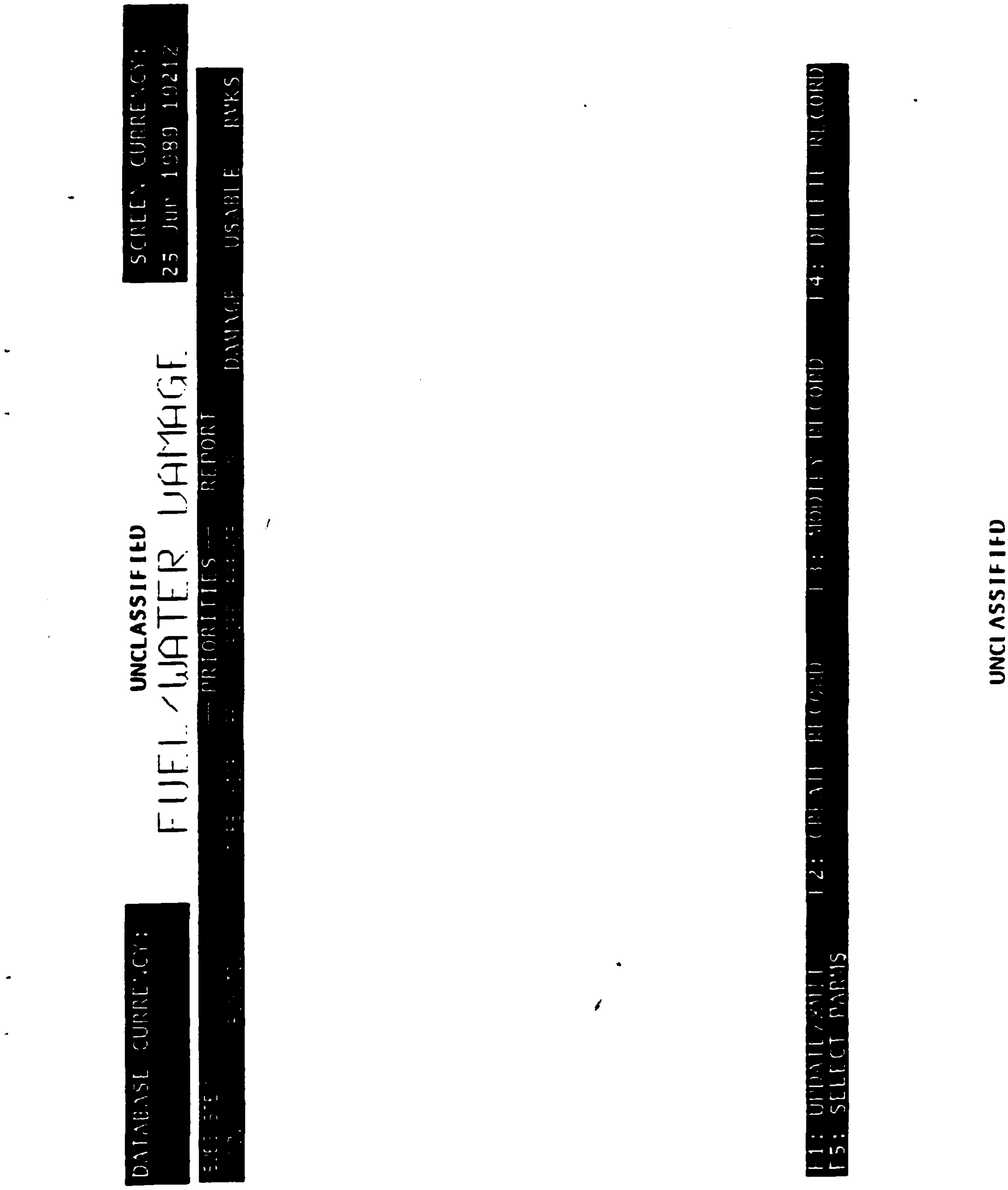


FIGURE 16: FUEL/WATER DAMAGE SCREEN

REFERENCES

1. "Statement of Work," #AD-YQ86-1 Survivable BRAAT Communications System," Headquarters Munitions System Division, (AFSC), Deputy for Air Base Operability (MSD/YQ), Elgin AFB, January 1986.

2. "Software Requirements Specification for the Navy Damage Assessment and Control System (NDACS)," SofTech Inc., 14 June 1989.

3. "Final Test Report for the Navy Damage Assessment and Control System," SofTech Inc., 07 November 1989.

4. "Forward Naval Base Functions: Measuring their Contributions to Warfighting Effectiveness," NCEL Technical Memorandum 03B-88-01, September 1988.

5. "Software User's Manual for the Navy Damage Assessment and Control System (NDACS)," SofTech Inc., 13 September 1989.

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