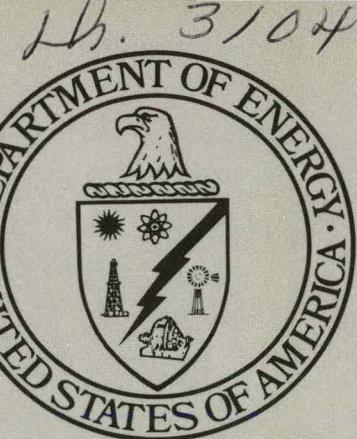


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## BUILT IN TEST EQUIPMENT (BITE) TO IMPROVE FRONT END LOADER PRODUCTIVITY

Technical Progress Report  
Contractor—McDonnell Douglas Electronics Company

May 1981

Contract No. U.S.D.O.E. AC22-80ET14052



**U. S. Department of Energy**  
**Assistant Secretary for Fossil Energy**  
**Office of Coal Mining**

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(DE81022404)  
Distribution Category UC-88

# **BUILT IN TEST EQUIPMENT (BITE) TO IMPROVE FRONT END LOADER PRODUCTIVITY**

**TECHNICAL PROGRESS REPORT  
MCDONNELL DOUGLAS ELECTRONICS COMPANY**

**May 1981**

**U.S. DOE DE-AC01-80ET14052**

**U.S. Department of Energy**  
Assistant Secretary for Fossil Energy  
Office of Coal Mining

### ABSTRACT

This Topical Report describes an equipment system being developed to improve the availability and productivity of large front end loaders used in surface mining operations. The equipment is mounted on the front end loader and includes an operator display and keypad, a microcomputer, machine sensors and a signal conditioner. Safety and machine performance problems are displayed to the operator and a report is printed for the maintenance shop. The BITE equipment, environment and system operation are described.

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## 1.0 EXECUTIVE SUMMARY

The Built In Test Equipment (BITE) to Improve Front End Loader (FEL) Productivity contract was awarded in September 1980. Since that time McDonnell Douglas Electronics Company (MDEC) has completed the preliminary design task and has begun to fabricate and assemble a single breadboard system that will be ready for bench testing in August 1981. This report describes the breadboard system.

The preliminary design task consisted of reviewing previous Dept. of Energy reports, reviewing the stability indicator work being developed by the Bureau of Mines, reviewing FEL systems and applicable sensors, and conducting FEL tests to define the BITE environment.

The goal of the BITE system is to improve the availability and productivity of large FELs, 10 cubic yards and above. The approach being employed is to:

- ° Develop a cost effective base system, adaptable to various makes and sizes of FELs.
- ° Develop displays to improve operator safety and performance.
- ° Develop displays to alert the operator of servicing requirements and abuse of the FEL.
- ° Develop on-board maintenance and productivity displays.
- ° Develop maintenance reports for identifying and logging FEL problems and utilization.

A BITE system block diagram is shown in Figure 1. The components located in the FEL cab are a 32 character liquid crystal display (LCD), 16 pushbutton keypad, FEL stability indicator display, and microcomputer. The signal conditioner is a separate box located in the hydraulic or engine compartment. Signal conditioner functions are to supply reference voltages to sensors and supply sensor data in digital form to the microcomputer. FEL sensors are located throughout the FEL. Sensors have been classified as machine parameter sensors or operation parameter sensors. The machine parameters monitor FEL subsystem performance. The operational parameters monitor FEL use.

The tape unit and printer are kept at the maintenance shop. The tape unit is portable and is taken to the FEL to get data. The maintenance report is a summary of operator messages that were issued since the last time that data was collected.

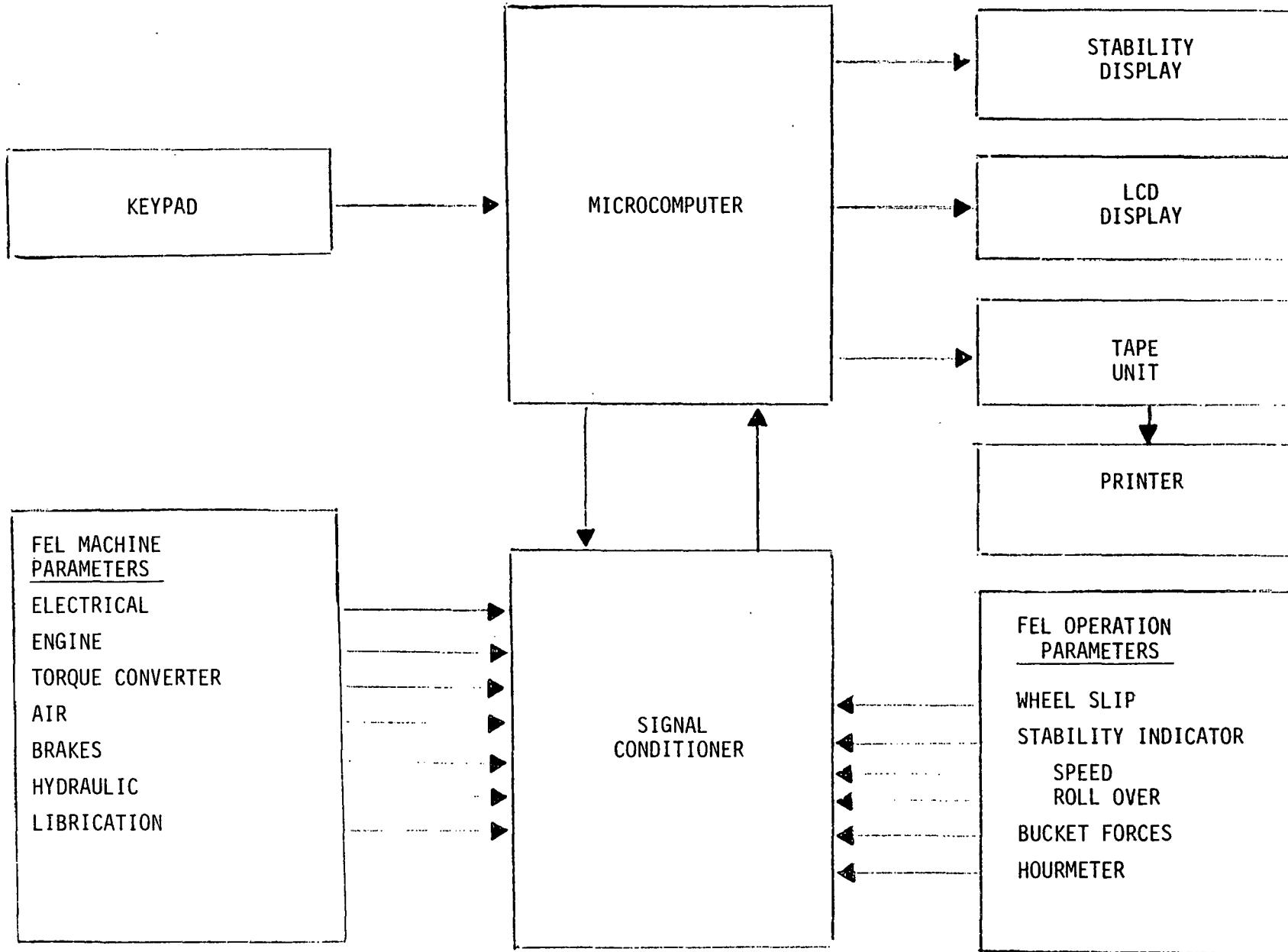


FIGURE 1  
BITE SYSTEM BLOCK DIAGRAM

## 2.0 BITE HARDWARE

The BITE system described in this report is the result of several background studies and evaluations that were performed. These included:

- o Reviewed concepts developed by Skelly and Loy, Ref. 1, 2 & 3.
- o Reviewed FEL stability indicator being developed by the Bureau of Mines.
- o Inspected instrumentation displays and available space in the cabs of Caterpillar, Dart, John Deere, and LeTourneau machines.
- o Reviewed common machine subsystems and monitoring devices.
- o Reviewed methods of presenting information to the FEL operator and maintenance personnel.
- o Conducted field tests to define the operating environment.
- o Reviewed components, sensors, and technology applicable to a BITE system.

## 2.1 Design Considerations

The background studies led to the establishment of the BITE design considerations which includes the definition of the BITE operating environment, and how to package the system so that it can be maintained by mine maintenance personnel.

### 2.1.1 Environment

A major area of concern for any electronic system is operating environment. FEL's operate under many environmental extremes throughout the coal producing regions of the United States. Temperature extremes, vibration, and electro-magnetic compatibility are critical design parameters. The BITE environmental design specifications are listed in Table 1.

#### Temperature

Ambient temperature extremes can range from an over-night low of  $-55^{\circ}\text{C}$  in Northern climates to a high of  $+55^{\circ}\text{C}$  in the coal surface in Southern climates. Machine generated heat from normal operation also increases the total temperature that the system will be exposed to. To meet these extremes, when applicable military grade components have been selected.

Commercial grade components typically have an operating temperature range of  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$  and are packaged in plastic cases. Both the low temperature range and plastic case are unsuitable for the FEL environment. Hermetically sealed ceramic cased components must be used to protect against humidity problems.

The majority of military grade components are available only with a  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  operating range. Some of the more expensive components such as the processor and math chips are available in two temperature ranges. To reduce costs, an operating range of  $-55^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  is selected when available.

TABLE 1  
BITE ENVIRONMENTAL DESIGN SPECIFICATIONS

Temperature

Operating:	-40 <sup>0</sup> C to +85 <sup>0</sup> C
Non-Operating	-55 <sup>0</sup> C to +125 <sup>0</sup> C

Humidity

Maximum:	100% RH at 65 <sup>0</sup> C
Condensation:	Yes
Frost:	Yes

Mechanical Shock

Magnitude	 1
Waveshape	

Vibration

Machine Frame	 1
Bucket and Boom	 2

3g rms  
5g rms

Electromagnetic Interference

Conducted AC Voltage	3 volts rms
Electric Field Intensity	20 Volts per meter
Transient Protection	
Voltage	141 volts peak
Duration	50ns to 500 us

Dust

Concentration	1000 mg/m <sup>3</sup>
Mean Size	0.5 to 3 microns



MDEC will perform test environment surveys and mine field tests to define the environment.



MDEC interprets the vibration requirements to be random vibration with a flat spectrum from 5 to 500 HZ at the indicated overall acceleration levels.

### Vibration

Preliminary FEL shock and vibration data was obtained by instrumenting a 15 cubic yard Dart 600C loader operating at the factory test site. This was done primarily to verify instrumentation points and test procedures. Triaxial accelerometers were initially located on the FEL at the bucket pivot pin and the hydraulic bucket tilt ram. The tests were repeated with the accelerometers mounted on the floor and dashboard of the cab, and on the engine compartment.

Data was recorded for the following maneuvers:

Bucket tilt to stop

Empty bucket maximum lift rate to stop

Empty bucket dump

Empty bucket slam on ground

Complete load and unload of loose dirt

High engine RPM run

The maximum shock measured was 21.2g for a duration of 40 milliseconds in the vertical direction at the bucket pivot pin when the empty bucket was slammed on the ground.

The following observations were made during the tests:

- o Most shock and vibration inputs originated at the bucket and boom structures and are greatly attenuated as they are transmitted to the cab and center pivot point.

- o Low level periodic vibration, originating from rotating machinery, was present at all accelerometer locations except the bucket pivot pin and hydraulic bucket tilt ram.
- o Spectrum analysis data revealed no significant response frequency above 50HZ.
- o The response data was basically shock transients with a long pulse duration that was initiated at the bucket.
- o The maneuvers that extended the FEL bucket to the stops were probably as severe as can be expected at a mining operation.
- o The pile of loose dirt was not representative of material that is normally loaded at a mining operation.
- o The ground terrain was not representative of an actual mining operation.

The tests will be repeated on a FEL removing overburden after the resolution of the United Mine Workers contract.

## Electromagnetic Interference (EMI)

Because EMI characteristics of large FELs could not be found in the literature or obtained from manufacturers, survey tests were conducted on a Dart 600C diesel-mechanical and a LeTourneau L700 diesel-electric machines. This data will be used to minimize the risk of electromagnetic incompatibility between FEL wiring and co-located BITE electronic units and cables. Digital circuits are particularly susceptible to upset from transients coupled to inputs of these circuits. Therefore, consideration was limited to measuring only the peak level of FEL transient emission.

Conclusions reached from the experimental data are as follows:

- ° Transient voltages coupled from the electric-drive FEL are two orders of magnitude more intense than those coupled from the mechanical-drive FEL.
- ° The highest coupled transient voltages is 141 volts and occurs when engine start is initiated.
- ° Other than engine start, the highest coupled transient voltages occur when forward motion is initiated on the electric-drive FEL. The measured transients were 36 volts at the DC cable on the left side of the cab and 125 volts at the AC generator output cable.

- o BITE circuits on an electric-drive FEL must be both shielded and common mode protected by the use of isolated signal loads or differential line receivers.

Cable shielding generally yields a minimum shielding effectiveness factor of about 100. With shielding alone, coupled transient voltages during engine start and the initiation of forward motion would exceed the 1.0 volt noise margin of single-ended digital circuits. Differential signal load circuitry will also be used. It generally provides a 15 volt noise immunity.

### 2.1.2 Maintenance

Maintainability or the ease of maintenance has been defined as a significant BITE performance characteristic. The BITE maintenance philosophy is that the system will be capable of fault isolation to the defective subassembly and/or circuit module and replacement of the defective item by mine personnel. The following maintainability features have been established as design goals:

- ° The BITE system will not contain any devices that require scheduled maintenance. Typically, these are items such as filters, tape reader heads, rotating devices requiring periodic lubrication, etc.
- ° At "Power On", the BITE system will automatically perform a self diagnostics routine in order to determine the ability of the BITE to analyze the operational readiness of the front end loader. If there is a fault encountered with the condition of the BITE, this will be indicated in a display presentation, which is part of the BITE system. The display will also indicate which replaceable module is defective.
- ° A failure in the BITE system shall not impede operation of the front end loader.
- ° The mean time to repair (MTTR) of the BITE system shall not exceed one hour.

- ° All electronic circuitry will be housed in environmentally sealed enclosures suitable for rugged environments. All input/output connections to the electronic enclosures will utilize environmentally sealed connectors.
- ° Circuits will be modularized so that failures can be fault isolated to a single circuit card. These cards will be designed as plug-in modules with attached cam-action extractors.
- ° Reference designators will be utilized on all circuit cards and their proper positions within the enclosure marked with a corresponding reference designator.
- ° All sensors will be either "discard at failure" type or can be repaired by replacement of a defective sensing element.

## 2.2 BITE Components

The BITE system has six major subsystems: the keypad, display, microcomputer, signal conditioner, sensors, and maintenance report printer. The sensors have been classified according to function as machine parameters and operation parameters. The machine parameters monitor FEL subsystem functions. The operation parameters are a collection of parameters that monitor how the operator is utilizing the FEL.

### 2.2.1 Keypad

A mock-up of the breadboard keypad is shown in Figure 2. An internal circuit card protects against contact bounce and provides serial data transmission to the microcomputer.

The selected keypad is designed for use in adverse environments. The surface of the keypad is covered with a one-piece neoprene elastomer which seals out oils, grease, water, dust, and sand. The keypad is suitable for gloved hand operation. The performance specifications are:

Operating Temp:	-30 <sup>0</sup> C to 71 <sup>0</sup> C
Key Spacing:	.75 inch
Key Travel:	.10 inch
Operating Force:	15 ounces nominal
Life:	500,000 operations

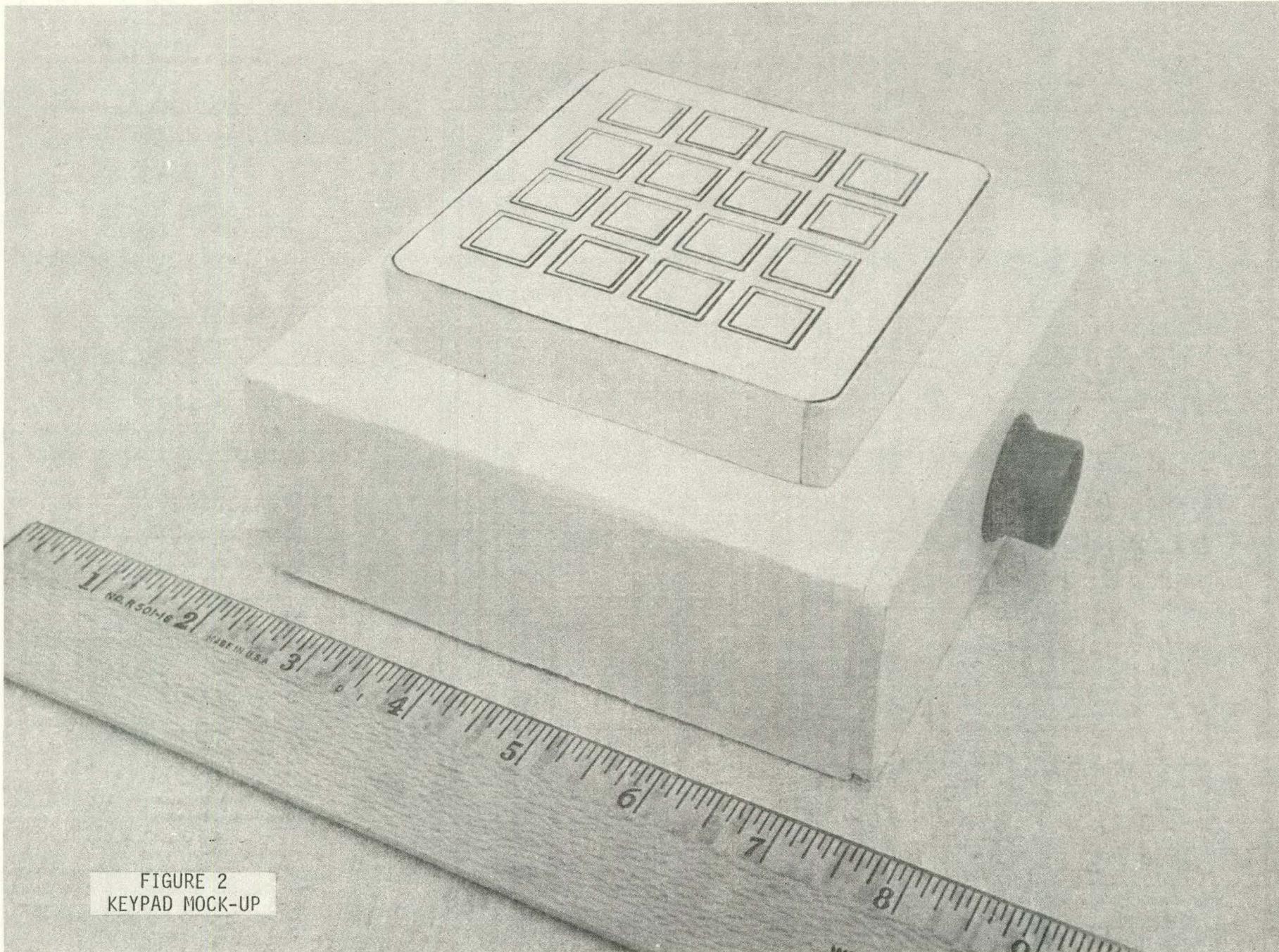


FIGURE 2  
KEYPAD MOCK-UP

### 2.2.2 Display

A mock-up of the breadboard display is shown in Figure 3. The display has 32 characters arranged in two rows of 16. Each character is .3 inches high and is presented in a 5 x 7 dot matrix format. Special characters and symbols are possible.

A liquid crystal display was selected because of their desirable characteristics of ultra low power consumption and high contrast ratio in bright sunlight. The unit is back lighted for night operation.

The operating temperature range of the LCD is -20°C to 70°C. The low temperature limit will be extended by the use of display heaters. Display response times will be very slow until the display warms up.

### 2.2.3 Microcomputer

The microcomputer will monitor the FEL subsystems, provide the operator with status information, and generate data for hard copy reports. The microcomputer is based on the Z8002 microprocessor. This is a 16-bit device capable of executing byte as well as word instructions. A sixteen-bit processor was chosen for several reasons. MDEC experience with the Dragline Information Gathering System (DIGS) has shown that a system whose main function is to gather and display information must have greater processing power and higher throughput than one that is merely collecting data. Also, since the software will evolve continuously to meet ever-changing customer requirements, programming must be done in a high-level language. A real-time application using a high-level language requires powerful and flexible processor. The Z8002 was selected after examination of the available processors and was

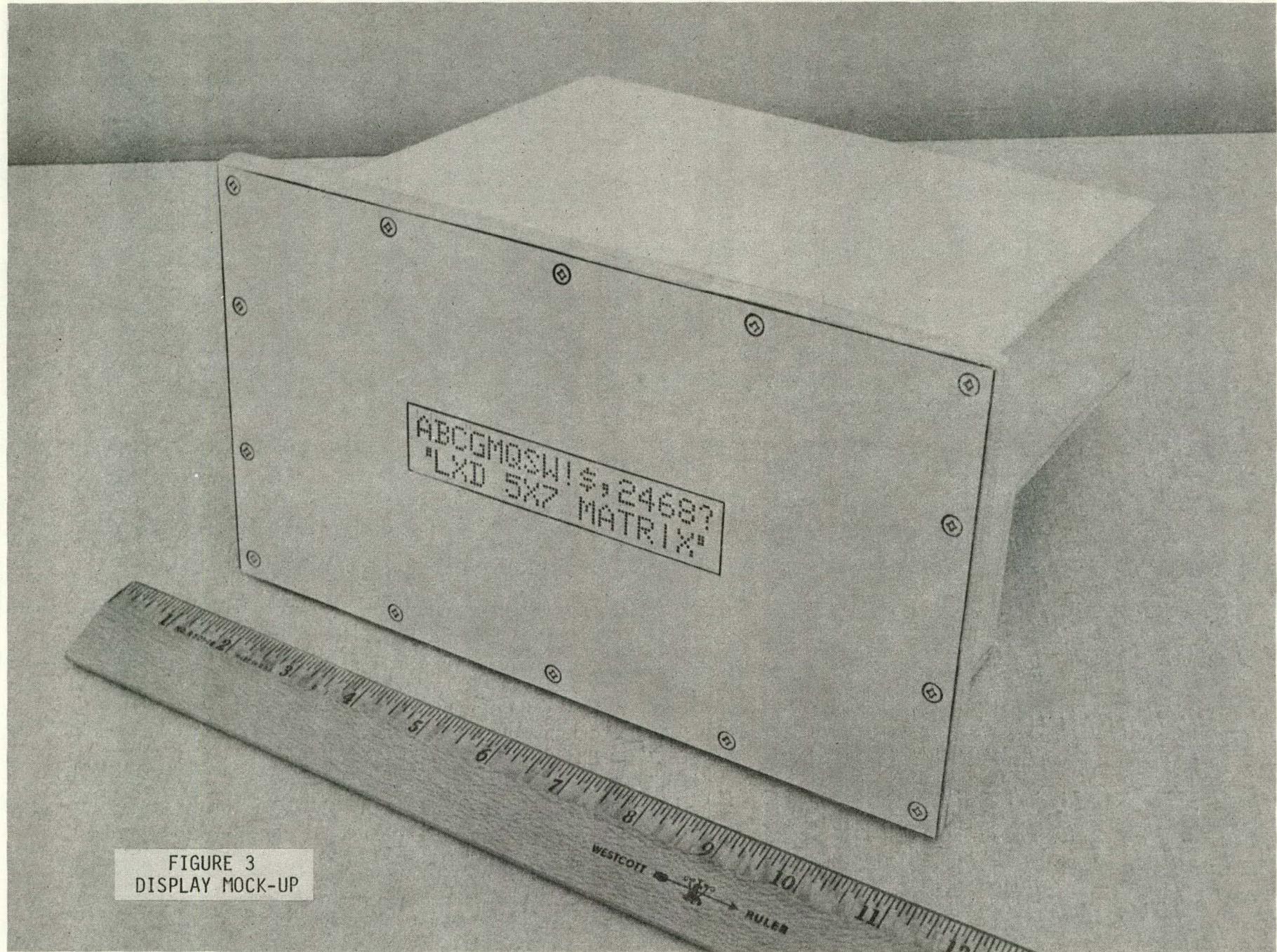
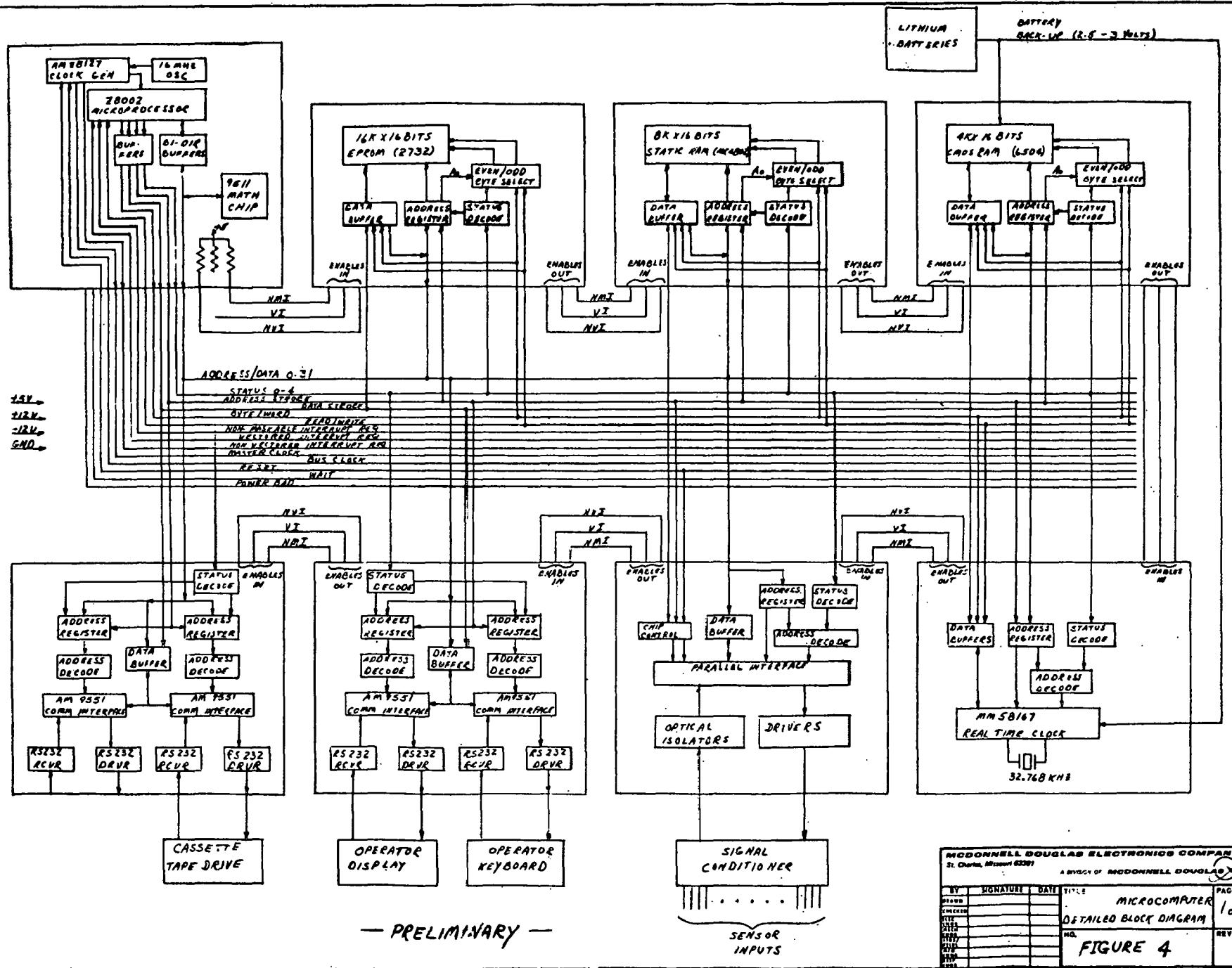


FIGURE 3  
DISPLAY MOCK-UP

deemed best able to fulfill the above requirements in a mining environment. A preliminary block diagram of the microcomputer is shown in Figure 4. The system is organized around the Zilog Z-Bus Interconnect.

Memory will be composed of 8K words of random access memory (RAM) and 16K words of erasable-programmable read only memory (EPROM). An additional 4K words of RAM will be battery-powered when system power is off to retain data. These allocations are preliminary and provisions have been made to allow increasing or decreasing quantities of different types of memory as required.

An additional 1024 word memory will be placed in the input/output (I/O) address space for the purpose of holding the machine personality constants required to "fine-tune" the BITE system to a particular FEL. This memory will consist of a part that is actually two memories in one. To the rest of the system, it appears to be a RAM, but that RAM is actually backed up by an electrically erasable PROM (EEPROM). The contents of the RAM may be written into or read from the EEPROM at will. The device requires a single 5 volt supply and is ideally suited to storing parameters that are essentially permanent but may need occasional updating. Battery back-up would be impractical here because the constants could be lost and have to be re-entered when the battery is replaced or if it is allowed to discharge.



A real time clock is incorporated that keeps track of time down to thousandths of seconds. It can generate interrupts as fast as every tenth of a second which the processor can use as a real base for checking data acquisition registers. The clock will also be backed up by a battery so that it will continue running even when the rest of the system is not in operation.

Lithium batteries have been chosen for the real time clock and battery backup RAM circuits because of their high terminal voltage and high energy density. These devices have a 2.8 to 3 volt output and have a very flat discharge characteristic. Being non-rechargeable, when they reach 2 volts they are considered dead. They have a wider operating temperature range (-54<sup>0</sup>C to 74<sup>0</sup>C) than almost any other battery. As an example of their energy density, a D-size lithium battery has the capacity to power the 4K words of memory and the real time clock continuously for one year. Since the battery is to serve as a back-up function to a system power supply, life expectancy will be on the order of three years.

Parallel communication will be used to handle data interchange with the signal conditioner. The signal conditioner is that portion of the BITE system which will interface with the FEL and perform analog to digital conversion, detect discrete switch position and count pulse trains from proximity sensors mounted on the machine's axles. The parallel interface will provide separate 16-bit input and output ports. Optical isolation will be used at the receiver ends of the parallel cables to prevent potentially damaging voltages from being conducted into the processor enclosure.

Serial input and output data will be via an RS-232C compatible interface. A programmable communication interface circuit will provide modem control so that each port can provide a full RS-232C implementation or data transmission and reception portions of the standard. Serial I/O will be used to communicate with the operator display and keypad. In addition, communication will be possible with a variety of terminals, a modem, or any device compatible with RS-232C.

#### 2.2.4 Signal Conditioner

The signal conditioner interfaces the FEL subsystem sensors to the micro-computer. It provides excitation and reference signals to the sensors, provides electrical isolation from the FEL power and ground system, converts the sensor signals to digital format and transmits the data to the micro-computer.

The possibility of purchasing commercial units such as the Micro Mac 4000 Series built by Analog Devices and Sinealab were investigated. The units were too expensive (\$8,000), provided extra features that would not be utilized, and were not designed for operation in a mining environment. The decision was made to design a signal conditioner that is expanded by picking and choosing the required number of functional circuit cards. The signal conditioner uses independent multiplex bus system to minimize the cables between the conditioner and microcomputer.

Five circuit cards have been designed to interface temperature, pressure, position, force, speed, and stress signals. Optical isolation is used between the circuit cards and FEL sensors to prevent potentially high voltages from damaging the signal conditioner. A block diagram of the system is shown in Figure 5.



The Interface Buffer and Discrete Input/Output circuit board interfaces the microcomputer to the signal conditioner system by means of sixteen (16) parallel input and sixteen (16) parallel output data lines. After buffering, the input/output data lines are distributed through the circuit board and bussed to the backplane as the signal conditioner bus. This card can accept thirty-two (32) input discretes and provide sixteen (16) output discretes to interface external circuits.

The digital counter circuit board contains three counter circuits consisting of address control, input latch, digital counter, and input sensor isolation circuits. The three counter control circuits will receive digital count pulses from sensors on the engine output drive shaft, one rear wheel axle, and one front wheel axle. The microcomputer will address each counter in succession and read the accumulated counts. When the address lines are decoded to read the counter information the address pulse is delayed and used to reset the counter to make ready for the next series of sensor input pulses.

The analog to digital (A/D) converter circuit board consists of four parts. The address control, the output latch, the convert command control, and the converter module. The A/D converter has sixteen input channels which are multiplexed and addressed in succession onto the signal conditioner bus through the output latch.

The Low Level Signal Conditioner will contain all necessary circuitry to interface parameters from sensor such as, pressure, temperature, force, stress, angular, and acceleration. This circuit board will not be connected to the data bus. All output will be routed to the analog input converter. The circuit configuration will have five (5) analog potentiometer signal conditioners, twelve (12) analog bridge signal conditioners, one (1) AC bridge signal conditioner, and the 10VDC bridge excitation reference. The circuit will continuously output present data to the A/D converter for transfer to the microcomputer.

The High Level Signal Conditioner circuit board will contain all voltage inputs greater than 5VDC and can handle voltage up to 1000 VDC. Because of the possibility of high voltage existing on this device, the circuit card will be isolated from the signal conditioner chassis and contained in a safe enclosure of its own. The output will be scaled to  $\pm 5$  VDC maximum signal and routed to the A/D converter for transfer to the microcomputer.

## 2.2.5 Machine Parameters

Machine parameters will be monitored by sensors located in the major FEL subsystems such as the electrical, engine, torque converter, air brakes, hydraulic, lubrication, and nitrogen systems. Existing FEL sensors are used whenever possible. Many signals are already available at terminal board locations.

Table 2 identifies the sensors used by each major system. The table identifies existing FEL sensors, type of signal, the sensor range, and the warning sense point. The operating ranges and warning sense points were established by consultation with manufacturers and review of FEL manuals. The warning sense points are stored in the personality module so they can be adjusted for different machines.

## ELECTRICAL SYSTEM

The following electrical system sensor will be added:

### **Battery voltage level**

The battery voltage level will be used to verify that the charging system is operating. The normal charging range is 27.5 to 28.0 volts. Over voltage and under voltage machine performance alerts will be issued if the battery voltage is out of range when the engine is running. If the battery drops below 22.0 volts, a low battery alert will be issued. The number of occurrences of each malfunction will be printed on the maintenance report.

TABLE 2

BITE FEL SENSOR CHARACTERISTICS

PARAMETER	MANUFACTURER INSTALLED	SENSOR RANGE	SENSOR SIGNAL TYPE	WARNING SENSE POINT
<u>ELECTRICAL SYSTEM:</u>				
Battery Voltage		0-30V DC	Analog	<22VDC
<u>ENGINE:</u>				
Speed		2400 RPM	Digital	
Oil Press		0-200 PSI	Analog	
Coolant Temp		0-250 <sup>0</sup> F	Analog	>200 <sup>0</sup> F
Fuel Press			Discrete	
Air Filter Press			Discrete	
<u>TORQUE CONVERTER:</u>				
Oil Temp	Yes	100-300 <sup>0</sup> F	Analog	>275 <sup>0</sup> F
<u>AIR SYSTEM:</u>				
Main Tank Press		0-200 PSI	Analog	<85 PSI
<u>BRAKE SYSTEM:</u>				
Front Brake Malfunction	Yes	Differential	Discrete	△200 PSI
Rear Brake Malfunction	Yes	Differential	Discrete	△200 PSI
Parking Brake On	Yes		Discrete	
Emergency Brake On	Yes		Discrete	

TABLE 2 (Continued)

BITE FEL SENSOR CHARACTERISTICS

PARAMETER	MANUFACTURER INSTALLED	SENSOR RANGE	SENSOR SIGNAL TYPE	WARNING SENSE POINT
<b><u>HYDRAULIC SYSTEMS:</u></b>				
Reservcir Filter	Yes	Differential	Discrete	15 PSI
Reservoir Level	Yes		Discrete	Factory Set
Reservoir Temp	Yes	0-250 <sup>0</sup> F	Discrete	>200 <sup>0</sup> F
Pump #1 Case Temp		0-250 <sup>0</sup> F	Discrete	>200 <sup>0</sup> -225 <sup>0</sup> F
Pump #2 Case Temp		0-250 <sup>0</sup> F	Discrete	Adjustable
Pump #3 Case Temp		0-250 <sup>0</sup> F	Analog	
Particle Detectors			Discrete	
Oil Cooler Input Press		0-100PSI	Discrete	<50 PSI
Oil Cooler Flow		0-130 GPM	Discrete	<40 GPM
Oil Cooler Output Temp		0-250 <sup>0</sup> F	Analog	>180 <sup>0</sup> F
Lift Cyclinder Temp - Right		0-250 <sup>0</sup> F	Analog	△15 <sup>0</sup> F
Lift Cyclinder Temp - Left		0-250 <sup>0</sup> F	Analog	△15 <sup>0</sup> F
<b><u>LUBRICATION:</u></b>				
Lube Solenoid	Yes	Time Adjustable	Discrete	At lease every 80 minutes
<b><u>NITROGEN SYSTEM:</u></b>				
Oil Refill		0-6"	Discrete	>6"
Oil Press		0-3000 PSI	Discrete	<1500 PSI

TABLE 2 (Continued)

PARAMETER	BJTE FEL SENSOR CHARACTERISTICS			WARNING SENSE POINT
	MANUFACTURER INSTALLED	SENSOR RANGE	SENSOR SIGNAL TYPE	
<u>WHEEL SLIP:</u>				
Front Right Wheel Rotation Counter		12 Bit	Digital	Absolute
Rear Right Wheel Rotation Counter		12 Bit	Digital	Absolute
Transmission Output Shaft Counter		12 Bit	Digital	Direction
Articulation Angle		$\pm 40^0$	Analog	
<u>STABILITY INDICATOR:</u>				
Pitch Angle		$\pm 12^0$	Analog	
8 Strain Gauges on Front Axle			Analog	
<u>BUCKET FORCES:</u>				
Boom Left Pressure		0-3500 PSI	Analog	
Bucket Tilt Pressure		0-3500 PSI	Analog	Relief at 2250 PSI
Boom Height			Discrete	Truck/Train Load Height
Bucket Accel Switch Longitudinal			Discrete	Ramming
Bucket Accel Switch Vertical			Discrete	Dropping
<u>HOURMETER:</u>				
Calculated from existing sensor information.				

## ENGINE

The following engine sensors will be added:

- Engine speed
- Oil Pressure
- Coolant Temperature
- Fuel pressure
- Air filter pressure switch

Engine oil pressure and engine RPM will be monitored. If the oil pressure is below an established value when the engine speed is above 1500 RPM, a machine performance alert will be issued. Checking the engine RPM eliminates spurious alerts at low engine speeds. This is most likely to occur in late summer when it is very hot. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

The minimum oil pressure limit will be established by consulting with the engine manufacturer. The engine RPM will be obtained by the addition of a magnetic pickup sensor.

Normal engine coolant temperature is in the range of 170<sup>0</sup> to 185<sup>0</sup>F. When the temperature reaches 200<sup>0</sup>F a machine performance alert will be issued. The number of occurrences will be printed on the maintenance report.

A positive pressure switch will be installed between the engine and fuel filter. A loss of pressure indicates that the filter needs replacing or that there is a fuel leak. A machine performance alert will be issued. The time of occurrence will be printed on the maintenance report.

The air pressure across the engine air filter will be monitored to determine when the filter needs cleaning or replacing. A machine performance alert will be issued when the pressure exceeds an established value. The time of the alert will be printed on the maintenance report.

#### TORQUE CONVERTER

The following existing torque converter sensor will be used:

Converter oil temperature

The normal torque converter oil temperature range is 180<sup>0</sup> to 225<sup>0</sup>F. If the temperature reaches 275<sup>0</sup>F a performance alert will be issued. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

#### AIR SYSTEM

The following air system sensor will be added:

Main air tank press indicator

The main air tank pressure sensor will issue govenor adjustment and air leak performance alerts. When the engine is running, the air pressure should be between 95 and 120 PSI. The average upper and lower tank pressures will be printed on the maintenance report.

Air leaks will be detected by a slow air pressure rise or if the pressure never reaches 100 PSI when the engine is started. The pressure recovery rate should be greater than 6 PSI per minute. A rapid pressure drop when the engine is shut off will also indicate leaks. This requires a BITE shutdown delay.

The existence of a leak will be identified in the maintenance report.

A safety alert will be issued if the air pressure drops below 85 PSI during normal FEL operation. This is the point at which the wig-wag drops into view. The display will indicate STOP USE EMER BRAKE. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

#### BRAKE SYSTEM

The following existing brake system signals will be used:

Front brake malfunction switch

Rear brake malfunction switch

Parking brake ON switch

Emergency brake ON switch

The brake malfunction switches will alert the operator that an unsafe operating condition exists. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

An operator safety alert will be issued if the engine is turned OFF and the parking brake is not engaged. This requires delaying the BITE system shutdown until the parking brake is set.

#### HYDRAULIC SYSTEMS

The hydraulic system has been subdivided into three systems, the reservoir, the pumps, and the steering.

HYDRAULIC RESERVOIR - The following existing reservoir sensors will be used:

Filter pressure switch

Reservoir level switch

Reservoir temperature switch

The filter pressure switch will signal that it is time to replace the 10 micron filters. The level switch indicates that the reservoir needs filling. The temperature switch indicates that oil temperature has exceeded 200<sup>0</sup>F, the machine should be stopped, cause located and corrected.

Machine performance alerts will be issued for each of the above conditions. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

HYDRAULIC PUMPS - The following hydraulic pump sensors will be added:

Pump case temperature switch

Pump case temperature

Particle detectors

Pump case temperatures will be monitored to determine over temp conditions which indicate pump problems. Adjustable temperature switches will be used on two pumps. The final temperature settings will be established during the field evaluation. The third pump will have an analog sensor to collect design data which will be reported in histogram format. Over temperature conditions will issue a machine performance alert. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

The development of a magnetic hydraulic oil particle detector is being investigated. The present concept would use a magnetized sensor that contains two electrodes separated by a calibrated gap. As the magnetic particles are deposited, a conductive bridge would be built between the electrodes. When the gap closes, a machine performance alert would be issued and the time of the occurrence would be printed on the maintenance report. The detector will have a thread mounting and can be removed for cleaning.

It is anticipated that approximately five particle detectors would be placed on the FEL. Parts for laboratory testing and development have been ordered.

HYDRAULIC STEERING - The following hydraulic steering system sensors will be added:

- Oil cooler input pressure
- Oil cooler flow switch
- Oil cooler output temperature

The oil cooler input pressure switch indicates that the steering system is pressurized. A loss of pressure will issue a safety alert. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

The oil cooler flow switch indicates a loss of steering pressure or a clogged or restricted cooler. This check will not be made if there is a loss of steering pressure. When the oil flow drops below 40 gallons per minute, a machine performance alert will be issued. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

The oil cooler output temperature will be reported in histogram format. A machine performance alert will be issued when the oil temperature exceeds 180°F. The number of occurrences and the time of the first occurrence will be printed on the maintenance report.

## LUBRICATION

The following existing Lincoln Lube system signal will be used:

### **Lube solenoid signal**

The lube system time interval is adjustable. BITE will monitor the solenoid signal to verify that the lube system is functioning on schedule. The BITE time constant will be stored in the personality module and adjusted to be slightly larger than the lube system time interval. A machine performance alert will be issued and the message PRESS LUBE SW will be displayed when the lube system fails to operate.

The possibility of adding a lube level sensor to assure that lubrication is available is being investigated.

## NITROGEN SYSTEM

The nitrogen or balanced boom system is a Dart specific system that functions as a counter balance to assist the conventional load raising mechanism of the front end loader. The following balanced boom sensors will be added:

Oil refill signal,

Oil pressure switch

The oil refill switch indicates that the hydraulic oil needs to be recharged. When the oil pressure switch indicates that the pressure has dropped to 1500 PSI, the nitrogen system needs charging. Occurrences of either condition will issue a machine performance alert and the time of occurrence will be printed on the maintenance report.

## 2.2.6 Operation Parameters

The operation parameters monitor how the operator is utilizing the machine.

Additional sensors are added to the FEL to monitor wheel slip, speed stability, roll-over stability, bucket forces, and an hour meter.

### WHEEL SPIN

The wheel spin monitor is intended to help reduce tire wear. The following sensors will be added:

Front wheel rotation counter

Rear wheel rotation counter

Transmission output shaft counter

Steering articulation angle

The rotation counters will be proximity type sensors. The wheel counters are absolute speed counters, they do not determine direction. The transmission shaft counter will include an additional sensor to determine the forward or reverse direction. The signal conditioner will accumulate the speed counts in separate registers which can be interrogated by the software. Following each interrogation the registers will be reset and begin accumulating counts again.

The maximum allowable wheel slip, the allowable speed difference between the left and right wheels without spinning, is calculated using the steering articulation angle. The relative wheel slip for each axle is the difference between the fastest and slowest wheel. The relative wheel slip is compared to the maximum allowable slip to determine if a wheel is spinning. If both

wheels are spinning on one axle and only one wheel is spinning on the other axle the maximum relative wheel slip will be between the non-slipping wheel and the other wheel on the axle.

The ground speed will be assigned to the speed of the slowest wheel. This calculated ground speed is also used by the speed stability system.

When wheel spinning is detected, an operator performance alert will be issued. The number of occurrences will be printed on the maintenance report. The wheel spin duration times will be accumulated and reported in histogram format.

This wheel spin monitoring system has the potential of being expanded into an automatic differential lock system. This system would automatically convert to a positraction drive when wheel spin is detected.

#### STABILITY INDICATOR

The stability indicator will function as both a warning device and training aid. As a warning device, the stability indicator will indicate that the FEL is approaching an unstable condition via a blue, green, yellow, and red indicator lights located in the operator's forward field of vision where it can be readily seen. The operator cannot take the time to look down at the LCD to discern the warning. The effect of the four lights is to give the operator an indication of the rate at which he is approaching a critical rollover or overspeed situation. The trip points will be stored in the BITE personality module so that they can be adjusted for different machines and during field trials. The display indicator lights will be dimmable for night operations.

As a training device, the stability indicator will provide inexperienced FEL operators with a visual indication of machine stability which they can associate with their seat of the pants feeling. At the present time, the only thing the operator knows is that he did not have any problem before, therefore he can push the machine just a little bit further. Through this process each operator establishes an operating envelop in which he feels comfortable. The stability indicator will establish a standard stability envelop for all operators and should reduce the time it takes the inexperienced operator to approach the safe operating limits.

#### SPEED STABILITY

This system will monitor the down hill grade, the bucket load, and ground speed. Some manufacturers mount caution placards in the cab which specify maximum safe operating speeds for different down hill grades. These machines have speedometers, not all machines do.

Unless someone tells the operator what grades he will encounter, he must make his own best guess and plan his speed accordingly. A typical placard indicates the following:

<u>Percent Grade</u>	<u>Miles Per Hour</u>	
	<u>Empty</u>	<u>Loaded</u>
4	17	17
8	16	14
12	12	9.5
16	8	6.5
20	6	6

The speed stability display will indicate the percentage of maximum safe operating speed as shown below:

<u>Warning Light</u>	<u>Percentage Max Allowable Speed</u>
Red	100
Yellow	75
Green	50
Blue	25

A histogram will be used to monitor and evaluate the speed stability indicator. The histogram will count the times that each threshold setting is exceeded.

#### ROLL OVER STABILITY

This system will employ a modified version of the Zero Wheel Load Detector developed by Stevens Institute of Technology under BOM Contract H0357114. This system uses strain gauges mounted on the front axle near each wheel to measure the normal load on the wheels. The basic principle is that the normal load on the upslope wheel decreases as the roll angle increases and finally becomes zero as the FEL rolls over.

Four strain gauges will be located on each axle wheel stub. The strain gauges will be mounted in two vertical planes. Each plane has one gauge on top of the axle and one gage on the bottom of the axle. By subtracting the moments between the planes, the side force component is eliminated and only the normal wheel force remains. The different cross-sections on tapered axle housing can

be compensated for by adjusting the moment scalings.

The initial trip points for the display indicator lights are shown below:

<u>Warning Light</u>	<u>Roll Angle</u>
Red	22°
Yellow	19°
Green	15°
Blue	10°

A histogram will be used to monitor and evaluate the roll over protection operation. The histogram will count the times that each threshold setting is exceeded.

#### BUCKET FORCES

The bucket forces will be monitored to determine bucket load and operator abuse of the machine. The following bucket force sensors will be added:

Boom lift pressure

Bucket tilt pressure

Boom height switch

Bucket acceleration switch - longitudinal

Bucket acceleration switch - vertical

The boom lift and bucket tilt hydraulic pressures will be monitored to estimate the bucket load. The boom height switch will indicate when to estimate the bucket weight. The weight will be estimated on the fly as the bucket is being lifted. The switch will be adjusted to be activated

only when the bucket is raised to a truck or unit train loading operations. The number of bucket loads will be counted and reported on the maintenance report.

It is planned to mount accelerometer switches near the boom bucket pivot point. The longitudinal signal along with ground speed will indicate bucket shock due to ramming a stock pile. The vertical signal will indicate bucket shock due to slamming the bucket on the ground. Detection signal will issue an operator performance alert and the number of occurrences will be printed on the maintenance report. Predetermined levels will be established by instrumenting a FEL removing overburden.

The boom lift and bucket tilt hydraulic pressures will be monitored 10 times per second to monitor hydraulic spikes induced by bucket shock in an effort to possibly eliminate use of the accelerometers.

#### Hourmeter

The BITE hourmeter obtains its information from the engine speed sensor and the microcomputer clock. Three hourmeters will be maintained. The first indicates the time since the last data dump. The second hourmeter accumulates time whenever the engine is turning over. The third hourmeter will accumulate the time that the engine operates at high idle. These times will be printed on the maintenance report.

## 2.7 Maintenance Report Printer

The maintenance report data accumulated by the BITE system is preformatted for printing, and retained in the microcomputer battery backed up RAM.

Maintenance personnel will transfer the data onto a portable tape recorder which is taken to the maintenance shop for printing.

The specific tape recorder and printer to be used have not been selected.

The possibility of using a Radio Shack TRS-80 computer system will be investigated. This system offers the advantages of a maintenance shop computer with display capabilities at a cost that is competitive with buying an intelligent tape deck and printer.

### **3.0 BITE OPERATION**

The BITE system has three major operational modes, the power-up self test, the operator displays, and the maintenance reports.

#### **3.1 Power-Up Self Test**

When power is initially applied to the BITE computer, the computer will automatically execute a self test diagnostic. The system will check signal continuity to the keyboard, display, and signal conditioner. During the initial power-up sequence, a message will be put out to the display telling the operator of the power up test. If the display is inoperative the message or what is left of it will remain to inform the operator that the display is not functioning. Communication to and from the keyboard will be tested and if it has failed a message will be sent to the display. Communications to and from the signal conditioner will also be tested and a message will be put on the display if it fails.

The operator will not be required to do anything for the power up self test diagnostic. All of the boards in the processor box will be checked for bus connection through an I/O board address and answer back routine. After completion of the self test diagnostic, the system will automatically perform the BITE functions.

The display will be tested by sending a message to the display and 3 seconds later the display will be requested to echo back that message.

The keyboard will be checked by sending a string of characters and the string will be echoed back to check against the original string.

The signal conditioner box boards will be checked for bus connection with a scheme similar to the processor box. The analog to digital converter and five volt power supply will be tested by running the five volts through the signal conditioner and checking the results against the acceptable range.

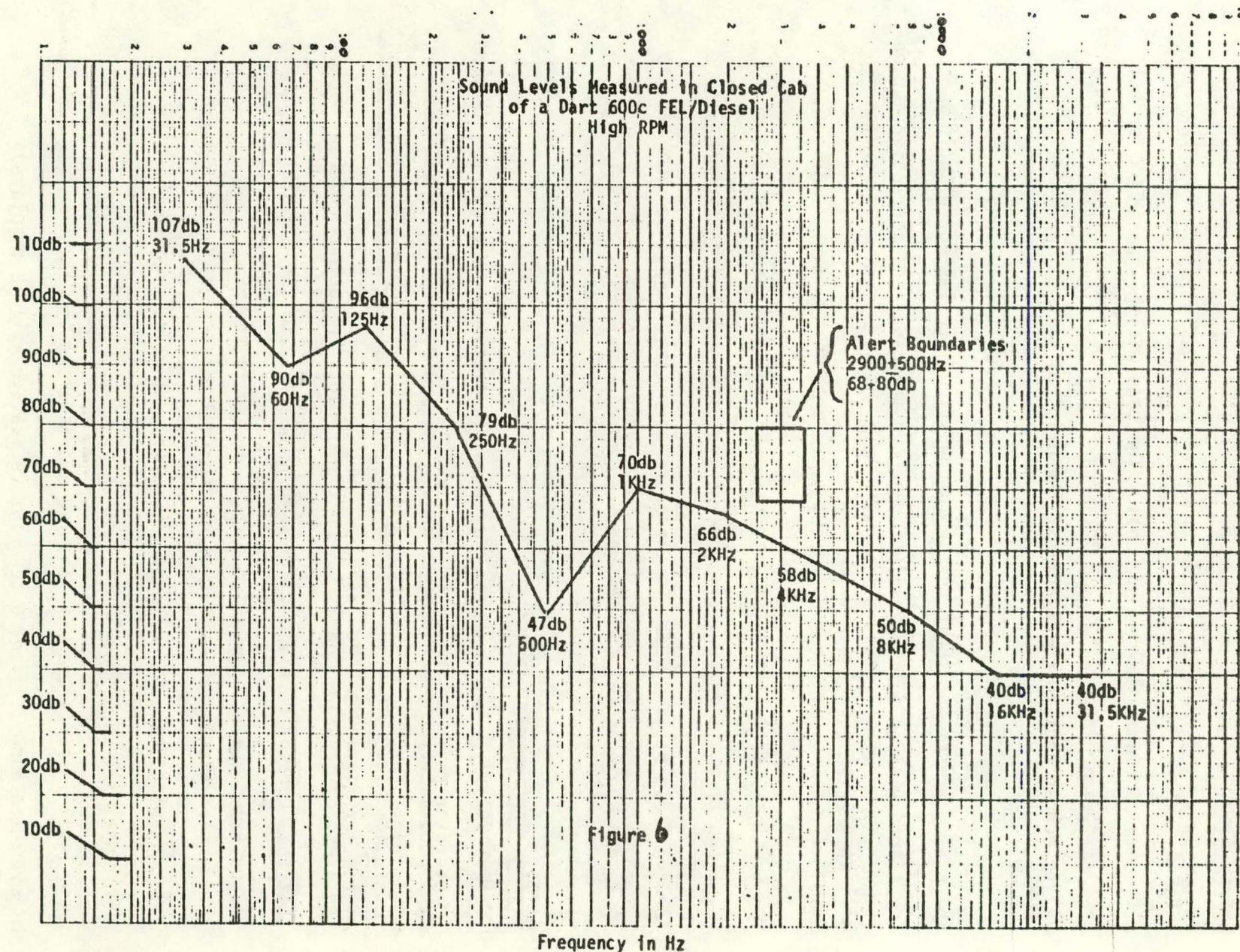
### 3.2 Operator Displays

The BITE information presented to the operator has been prioritized in descending order as alerts, meter mode displays, and maintenance displays.

#### Alerts

The BITE system monitors sensor data to generate safety, machine performance, and operator performance alerts. The alerts are prioritized such that a safety alert inhibits the machine and operator performance alerts, and a machine performance alert inhibits operator performance alerts.

Each type of alert is annunciated by separate distinctive audio signals. To avoid being masked by ambient FEL noise, the basic frequency of the audio tone will be  $2900 \pm 500\text{HZ}$  with an intensity of 68-80 DB. The ambient noise level in a FEL cab was measured and is shown in Figure 6. In addition to the audio annunciation, a descriptive message will be displayed.



### Safety Alerts

These alerts warn the operator that he is in danger. The audio annunciation will be a continuous series of beeps. The tone will be turned ON for half a second and OFF for one second. The audio will continue until the alert condition is rectified.

The safety alerts and their threshold conditions are listed in Table 3.

The alerts will be automatically issued and the cause and corrective action will be displayed on the LCD.

The stability indicator display lights will indicate speed and roll over stability alerts. The stability display will be located in the operator's forward field of view where it can be readily seen, so he does not have to look down to interpret the message.

### Machine Performance Alerts

These alerts warn the operator that something is wrong with the FEL and that he should notify the maintenance crew. The audio annunciation will be a continuous tone. The tone will be presented until the operator acknowledges the alert by pressing the OK key on the keypad. The acknowledgement insures that the operator received the message. It is up to the operator to determine if continued operation would result in damage to the FEL.

TABLE 3  
SAFETY ALERTS

<u>MESSAGE</u>	<u>CONDITION</u>
AIR LOSS - STOP! USE EMER BRAKE	<85 PSI
BRAKE MALFN-FRNT CAUTION	>200 PSI DIFFERENTIAL
BRAKE MALFN-REAR CAUTION	>200 PSI DIFFERENTIAL
STEERING PRESS LOW - STOP!	<50 PSI AT COOLER INPUT
PARKING BRAKE NOT ENGAGED	AFTER SHUTDOWN
SPEED STABILITY CAUTION	REF 2.2.6
ROLL STABILITY CAUTION	REF 2.2.6

The machine performance alerts are listed in Table 4. The alerts will be automatically issued and the cause and number of occurrences will be displayed on the LCD. The message will be displayed until the condition is corrected or until another alert is detected. The audible tone will be issued for every new occurrence of an alert condition. The display will alternate performance alert messages every 15 seconds when there are multiple warnings.

Operator Performance Alerts -

These alerts warn the operator that something is wrong with his operating procedure. The audio annunciation will be a repeating pattern that is ON for 500 milliseconds (ms), OFF for 250 ms, ON for 1250 ms, and OFF for 250 ms. This pattern will be repeated four times for a total duration of nine seconds.

The operator performance alerts are listed in Table 5. The alerts will be automatically issued and the cause will be displayed on the LCD for 30 seconds. To reduce operator annoyance, repeating the same alert will be inhibited for one minute.

TABLE 4  
MACHINE PERFORMANCE ALERT MESSAGES

ENG AIR FILTER RESTRICTED	XX	HYD OIL COOLER CLOGGED	XX
ENG OIL PRESS LOW	XX	HYD PUMP #1 HIGH TEMP	XX
ENG COOLANT TEMPERATURE	XX	HYD PUMP #2 HIGH TEMP	XX
TORQUE CONVERTER TEMPERATURE	XX	HYD PUMP #3 HIGH TEMP	XX
FUEL FILTER RESTRICTED	XX	HYD OIL CONTAM SENSOR #1	XX
AIR PRESSURE LEAK	XX	HYD OIL CONTAM SENSOR #2	
AIR COMPRESSOR ADJUST GOVENOR	XX	HYD OIL CONTAM SENSOR #3	
REPLACE HYD OIL FILTERS	XX	HYD OIL CONTAM SENSOR #4	
LOW HYD OIL LEVEL	XX	HYD OIL CONTAM SENSOR #5	
HIGH HYD OIL TEMPERATURE	XX	BALANCED BOOM LOW OIL LEVEL	XX
HYD OIL COOLER AIR FLOW	XX	BALANCED BOOM NITROGEN PRESS	XX
		BATTERY CHARGER INOPERATIVE	XX

TABLE 5  
OPERATOR PERFORMANCE ALERTS

<u>MESSAGE</u>	<u>CONDITION</u>
BUCKET SHOCK	DROPPING OR RAMMING
WHEEL SPIN	SPINNING

### Meter Mode Displays

The BITE LCD can be used in a meter mode to display running values of selected parameters. The parameters that can be selected are listed in Table 6. The operator selects the display parameters via the keyboard.

The BITE keyboard will have 16 keys with the following legends:

1	A B C 2	D E F 3	OK
G H I 4	J K L 5	M N O 6	DIAG
P R S 7	T U V 8	W X Y 9	DSPY
CLEAR	0		ENTER

After the system completes the power up self test diagnostic, the display will automatically display air pressure and time of day. They will remain until changed or overridden by an alert. The operator must use the keyboard to change the displayed parameters. New parameters are selected by pressing the DSPY key followed by the entry code and the ENTER key. The numeric entry code will be echoed on the LCD as the code is entered. The clear key will remove the last digit entered. Each time it is pressed, another digit will be removed. A wrong entry will result in an indication of NO SUCH THING.

TABLE 6  
METER MODE DISPLAYS

<u>PARAMETER</u>	<u>DISPLAY</u>	<u>SIGNIFICANT DIGITS</u>	<u>INPUT</u>	<u>CODES</u>
				<u>ECHO</u>
Time of Day	TIME	XX:XX	TOD	963
Engine Oil Pressure	ENG OIL PRES	XXX	EOP	367
Engine Coolant Temperature	ENG COOL TMP	XXX	ECT	328
Air Filter Pressure	AIR FILTER	XXX	AF	23
Tachometer	TACHOMETER	XXXXX	T	8
Fuel Filter Pressure	FUEL FILTER	XXX	FF	33
Hydraulic Oil Pressure	HYD OIL PRES	XXX	HOP	467
Hydraulic Oil Temperature	HYD OIL TMP	XXX	HOT	468
Hydraulic Pump Temperature	PUMP #1 TMP	XXX	P1T	718
Hydraulic Pump Temperature	PUMP #2 TMP	XXX	P2T	728
Hydraulic Pump Temperature	PUMP #3 TMP	XXX	P3T	738
Lift Pressure	LIFT PRES	XXXX	LP	57
Tilt. Pressure	TIILT PRES	XXXX	TP	87
Steering Pressure	STEER PRESS	XXXX	SP	77
Torque Oil Temperature	TORQUE OIL	XXX	TOT	868
Lube	LUBE	XXX	LLP	557
Air Pressure	AIR PRESSURE	XXX	AP	27
Hourmeter	HOURMETER	XXXXX	H	4
Programmable Parameter	PP 1	XXXXXX	PP2	771
Programmable Parameter	PP 2	XXXXXX	PP2	772

Each time a new parameter is entered for display, it will be shown on the top line of the display. The previous top line display is pushed down into the second line and the previous second line information is removed. To display engine coolant temperature, press the keys in the following order:

<u>KEY</u>	<u>TOP DISPLAY LINE</u>
DSPY	
E	3
C	32
T	328
ENTER	ENG COOL TEMP XXX

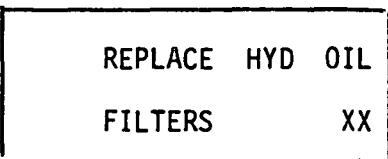
The air pressure initially displayed will disappear and the LCD will show:

ENG COOL TEMP XXX
TIME XX:XX

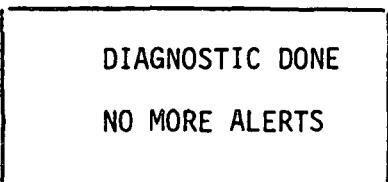
#### Maintenance Displays

The FEL operator or maintenance man can display, on the LCD, the machine performance data that will be printed on the maintenance report. This allows the FEL status to be checked without requiring a report to be printed.

The maintenance displays are activated by pressing the diagnostic (DIAG) key. The computer will search the maintenance alert list and display any alert which has occurred. The basic format is an abbreviated form of the maintenance report. The same descriptive title will be shown along with the number of occurrences. The date and occurrence time information will not be shown. A sample maintenance display is shown below:



Pressing the DIAG key again will find the next alert with any occurrences. When there are no more alerts to display, the LCD will show:



### 3.3 MAINTENANCE REPORTS

The maintenance reports are obtained by dumping the microcomputer maintenance data onto a cassette computer tape unit. After the data is dumped, the maintenance data memory area is cleared and data collection starts over. The tape unit is then taken to the maintenance shop where the report is printed.

The BITE computer and tape recorder both need power to transfer the data. The FEL can be in several conditions when this transfer takes place. There are three possibilities.

- o The machine is turned on with no tape drive plugged in.
- o The machine is turned on and the tape drive is plugged in at some time later.
- o The machine is turned off and the tape drive is plugged in.

The maintenance data will consist of five duration histograms and a listing of the warnings with the number of occurrences of each warning. Examples of the histograms are shown in Figures 7, 8 and 9.

The tape recorder is used to remove the maintenance data from the machine. The data can be removed with or without the engine running. The FEL electrical system does not have to be turned on to retrieve data. During the data dump the message "DATA DUMP" will be displayed.

The printer and tape recorder will be hooked together to generate hard copy maintenance reports. The tape unit will act as the printer driver.

## ENGINE OIL TEMPERATURE

JAN 5, 1981

## ACCUMULATED TIME IN MINUTES

	1000	2000	3000	4000	5000	6000
!	!	!	!	!	!	!

DEGREES	ACCUMULATED TIME IN MINUTES
<100	0.00000
100- 120	0.00000
120-140	45.36000
140- 160	201.60000
160- 180	4536.00000
180 -200	226.30000
200- 220	25.20000
220 -240	5.04000
240- 260	0.00000
260- 280	0.00000
280- 300	0.00000
> 300	0.00000

## ENGINE COOLANT TEMPERATURE

JAN 5, 1981

DEGREES	ACCUMULATED TIME IN MINUTES					
	1000	2000	3000	4000	5000	6000
<100	0.00000					
100- 120	0.00000					
120-140	45.36000					
140- 160	201.60000					
160- 180	4536.00000	*****	*****	*****	*****	*****
180- 200	226.30000	***	***	***	***	***
200- 220	25.20000	***	***	***	***	***
220- 240	5.04000	***	***	***	***	***
240- 260	0.00000	***	***	***	***	***
260- 280	0.00000	***	***	***	***	***
280- 300	0.00000	***	***	***	***	***
> 300	0.00000	***	***	***	***	***

### ENGINE RPM

JAN 4, 1981 - JAN 5, 1981  
% OF TIME SINCE LAST DATA COLLECTION

10            20            30            40            50            60

17

ZERO : 20.00000

1

## 1. IDLE

! \* \* \* \* \* \* \* \* \* \* :

<sup>1</sup> See, for example, the discussion of the 1992 Constitutional Conference in the *Journal of African Law* (1993) 37(1).

1

## OPER

! ☆☆☆☆☆☆☆☆☆☆☆☆

FIGURE 10  
MAINTENANCE REPORT

NUMBER OF OCCURANCES *****	NAME OF ALERT *****	DATE ****	TIME ****
ENGINE			
2	ENG OIL PRESS LOW	10/15/81	12:42
	ENG COOLANT TEMPERATURE		
1	FUEL FILTER RESTRICTED	10/15/81	9:05
1	ENG AIR FILTER RESTRICTED	10/16/81	1:56
TORQUE CONVERTER			
	TORQUE CONVERTER TEMPERATURE		
AIR			
	AIR LOSS - STOP! USE EMER BRAKE		
1	AIR PRESSURE LEAK	10/15/81	17:41
	AIR COMPRESSOR ADJUST GOVERNOR		
	AVERAGE LOWER AIR PRESSURE IN TANK	100 PSI	
	AVERAGE HIGHER AIR PRESSURE IN TANK	125 PSI	
BRAKES			
	BRAKE MALFN-FRNT		
	BRAKE MALFN-REAR		
1	PARKING BRAKE NOT ENGAGED		
2	BRAKES ENGAGED		
HYDRAULICS			
1	REPLACE HYD OIL FILTERS	10/15/81	16:17
	LOW HYD OIL LEVEL		
1	HIGH HYD OIL TEMPERATURE	10/15/81	16:32
	HYD OIL COOLER AIR FLOW		
	HYD OIL COOLER COOLER		
	HYD PUMP #1 HIGH TEMP		
	HYD PUMP #2 HIGH TEMP		
	HYD PUMP #3 HIGH TEMP		
	HYD OIL CONTAM SENSOR #1		

HYD OIL CONTAM  
SENSOR #2

HYD OIL CONTAM  
SENSOR #3

HYD OIL CONTAM  
SENSOR #4

HYD OIL CONTAM  
SENSOR #5

STEERING PRESS  
LOW - STOP!

LUBRICATION

\*\*\*\*\* 5

PRESS LUBE SW 10/15/81 23:58

NITROGEN  
SYSTEM

\*\*\*\*\*

BALANCED BOOM  
LOW OIL LEVEL

BALANCED BOOM  
NITROGEN PRESS

ELECTRICAL

\*\*\*\*\*

1

BATTERY CHARGER  
INOPERATIVE 10/15/81 11:11

OPERATOR

\*\*\*\*\*

32

BUCKET SHOCK

15

WHEEL SPIN

SPEED STABILITY  
CAUTION

ROLL STABILITY  
CAUTION

SITE

\*\*\*\*

NO

REPLACE BATTERY

INSTRUCTION SET  
PROBLEM OR ID

DISPLAY FAILURE

KEYBOARD  
INOPERATIVE

SIG CONDITIONER  
D I/G BOARD OUT

SIG CONDITIONER  
COUNT BOARD OUT

SIG CONDITIONER  
LLSG1 BOARD OUT

SIG CONDITIONER  
LLSG2 BOARD OUT

SIG CONDITIONER  
A/D 1 BOARD OUT

POWER OR CONVERT  
BAD ON A/D 1

ANALOG INP GROUP  
XX BAD ON A/D 1

SIG CONDITIONER  
A/D 2 BOARD OUT 64

POWER OR CONVERT  
BAD ON A/D 2

ANALOG INP GROUP  
XX BAD ON A/D 2

### 3.4 Personality Module

The FEL machine specific and BITE system adjustment constants will be grouped and stored in a personality module. This module is nothing more than an assigned section of microcomputer memory. These constants will be stored in non-volatile electrically erasable programmable read only memory (EEPROM) where they are immune to power losses but it is still possible to adjust the constants without recompiling and reprogramming a PROM for every different FEL. EEPROM is preferred to battery backup random access memory (RAM) because the data is locked into memory and does not need to be re-stored when the RAM backup batteries are replaced.

The personality constants identified to date are shown in Table 7. The initial constant values will be compiled into the BITE program. Changing the constants on the FEL can be performed by mine engineering personnel. This is not intended to be a FEL operator function. The steps to change a personality constant includes:

- o Enter a 3-digit secret meter mode display code.
- o Enter the identification number of the constant to be changed. The current constant value will be displayed.
- o Enter the new constant value if you want to change it.
- o Press the ENTER key. The display will automatically request another constant identification number.
- o Repeat steps 2 through 4 to change another constant, or press ENTER a second time to return the display to normal.

TABLE 7  
PERSONALITY CONSTANTS

1. Upper limit engine oil pressure
2. Lower limit engine oil pressure
3. Upper limit engine coolant temperature
4. Upper limit air filter pressure difference
5. Upper limit fuel filter pressure difference
6. Upper limit voltage
7. Lower limit voltage
8. Upper limit hydraulic oil pressure
9. Lower limit hydraulic oil pressure
10. Upper limit hydraulic oil temperature
11. Lower limit hydraulic oil level - while operating
12. Upper limit hydraulic pump case temperature
13. Upper limit hydraulic oil filter pressure difference
14. Upper limit hydraulic oil cooler pressure difference
15. Upper limit hydraulic cylinder pressure 1 for each cylinder circuit sensed
16. Lower limit hydraulic cylinder pressure 1 for each cylinder circuit sensed
17. Upper limit torque converter oil temperature
18. Front differential reduction ratio
19. Rear differential reduction ratio
20. Front final drive induction ratio
21. Rear final drive reduction ratio
22. Wheel diameter
23. Lower limit brake fluid pressure
24. Lower limit steering oil pressure
25. Upper limit steering oil temperature

TABLE 7  
PERSONALITY CONSTANTS (Continued)

26. Upper limit air pressure
27. Lower limit air pressure
28. Upper limit of allowable wheel slip
29. Stability limit (4)
30. Constants used to determine weight or bucket fill
31. Lower RPM for operating time to be accumulated
32. BITE Clock Hours
33. BITE Clock Min

#### **4.0 DEVELOPMENT TOOLS**

Several software development tools will be incorporated into the BITE system to facilitate system development and evaluation. These are engineering tools and are not intended for use by mining personnel. These tools include a keypad monitor, programmable histogram capability, and programmable meter mode capability.

##### **4.1 Keypad Monitor**

A data area will be set aside to monitor which meter mode displays the FEL operator and maintenance personnel use. This information will be used to determine the usefulness of the meter mode displays and to revise the meter mode displays at the end of the evaluation period.

##### **4.2 Programmable Histograms**

The maintenance report will include two keypad programmable histograms. These histograms are included to support BITE development. The steps to program the histograms include:

- o Enter a 3-digit secret meter mode display code.
- o Enter the identification number of the histogram to be changed.
- o Enter the address of the parameter to be monitored.
- o Enter the upper and lower histogram boundaries.
- o Press the ENTER key.

The upper and lower histogram boundaries program the scaling of the vertical histogram axis. The axis will be divided into ten equal segments with a below range and an above range indication on each end, see Figure 6. This flexibility permits expanding the histogram to cover the specific parameter range of interest.

The horizontal axis is fixed and will indicate duration time in minutes, up to a maximum of 6000 minutes or 100 hours.

#### **4.3 Programmable Meter Mode**

The LCD will have two programmable meter mode displays PP1 and PP2. These displays are included to support the BITE development. The steps to program the displays include:

- o Enter a 3-digit secret meter mode display code.
- o Enter the name of the display to be changed.
- o Enter the address of the parameter to be monitored.
- o Press the ENTER key.

The LCD will show either PP1 or PP2 and the numeric value of the selected parameter.

## 5.0 REFERENCES

Reference is made to the following documents in this report. The numerical designation of the references is shown below.

1. Built In Test Equipment (BITE) To Improve Front End Loader Productivity.  
DE-RP01-80ET-14052. Department of Energy, Office of Procurement  
Operations. July 1980.
2. Built-In Test Equipment for Front-End Loaders. Final technical report  
by Skelly and Loy. U.S. DOE contract No. DE-AC01-79ET11268.  
January 1980.
3. Built-In Test Equipment for Front-End Loaders - Phase II. Draft Final  
Report by Skelly and Loy. U.S. DOE contract No. DE-AC01-79ET11268.  
November 1980.