922408

Advanced EMR Technology

Authors: Peter Zieve, Laurence Durack, Brent Huffer, and Tim Brown

ABSTRACT

New EMR technologies have been developed in response to customer demand for better process control and reliability. In hand riveting of large panels visual contact between operators is blocked. A reliable means was required to insure that guns could only discharge when properly deployed upon opposing ends of the rivet. A second problem is to satisfy the demand for improved process control in EMR operation. These goals were achieved by implementing a fully digital control scheme for the EMR operation. These new technologies are covered in this paper.

SMART GUN

The smart gun system is currently in production on one aircraft program and is undergoing evaluation for use o a second program. In hand riveting of large panels visual contact between operators is blocked. There has been concern about potential damage if opposing handheld EMRs are pushed up against two adjacent rivets and discharged. Although normally the rivet would push into the hole without a backup gun present, giving indication to the operator, there might be an occasion when the rivet is jammed in the hole. The smart gun system addresses this concern.

Figure 1a shows two handheld EMRs properly positioned on the opposite heads of a rivet. Figure 1b shows the EMRs positioned up against adjacent rivets. If the guns should be fired in this position damage to the panel could result. The primary priority of the smart gun system is to prevent the EMRs from firing if the operators should inadvertently place the EMRs in this configuration. Figure 1c shows the handheld EMRs positioned on opposing sides of the same rivet but with one of the guns not properly normalized. A rivet formed in this fashion will be inferior to one formed with the guns properly normalized, therefore it would be advantageous for the smart gun system to also prevent firing in this situation. As implemented the smart gun system has been effective at distinguishing both of these types of gun positioning errors.

Figure 2 illustrates the operating logic which distinguishes the smart gun from the conventional handheld EMR system. In the conventional EMR system both EMR guns fire at the instant that both triggers, one on each EMR gun, are pulled. The smart gun has a more complex triggering sequence. In smart gun when both triggers are pulled just the smart capacitor bank fires. This is a small auxiliary capacitor bank, about 5% of the size of the main bank. The pulse which results from the smart bank is just a tap, not nearly enough force to deform a rivet.

The small force pulse takes about ½ millisecond to travel from the transmitting EMR coil, down the ram, the rivet, and down the second ram to be resolved into the receiving EMR coil. As shown in Figure 3 behind the receiving EMR coil is positioned a thin film piezoelectric force transducer. The force tap is sensed by the transducer. If the force signal from the load cell exceeds a settable threshold value in an adjustable time period the main EMR capacitor banks are discharged. The adjustable time period reflects the speed of sound and driver lengths for the particular EMR system. This operating logic is illustrated in the second part of Figure 2.

If the main EMR banks fire the resulting delay is under one millisecond and the presence of two force pulses cannot be detected by the operator. If the smart gun prevents the main capacitor bank from firing the operators will feel a small tap rather than the customary large impact of the EMRs.

Operation of the smart gun in the time domain is illustrated in Figure 4. First there is a small current pulse in gun 1. With a small time delay a signal is the registered by the smart gun piezo sensor. If the smart gun signal is below the threshold value the main capacitor banks will not fire as shown.

Conversely as shown in the lower half of Figure 4 if the threshold value for the smart gun signal exceeds the threshold value the main banks will instantly fire. Note that the voltage output from the piezo sensor will continue to rise up due to the increased pressure from the main EMR capacitor banks. This sensor will not be in any way damaged by the pressure resulting from riveting.

As you can see from the right half of Figure 4 both EMR actuators require special outfitting for use of the smart gun system. Gun 1 is the pulse transmitter with dual capacitor banks, the smart gun capacitor bank considerably smaller than the main bank. The opposing EMR, gun 2, must be equipped with the piezo sensor and detection circuitry. In current practice the smart gun transmitter is selected to be on the tail side of a headed rivet. This choice is made so that the smart gun pulse is not transmitted out to the wing panel rather than along the rivet to the opposing gun.

In order to provide feedback on the system operation a peak hold indicating meter on the smart gun signal is provided. By watching the output on this meter the operators can see the influence of improved alignment on the smart gun signal. The sensitivity adjustment is set in response to the signal values read off the indicating meter.

DIGITAL EMR CONTROLLER

For operation a low voltage EMR employs three electrical enclosures. Two enclosures contain the energy storage banks for the respective actuators. The third box is the controller. This paper discusses a new controller concept which has recently been introduced which takes advantage of enhancements in digital control technology. The paper highlights some of the process improvements which have resulted from the incorporation of this improved technology. Readers are encouraged to think of other “mature” processes in their facilities which could similarly benefit.

The first controllers were analog based and they responded to analog commands issued by the cell controller. These analog controllers were originally designed to mimic the high voltage EMR controls which they were designed to replace.

Progressively more and more demands were placed on these analog controllers. Customers demanded improved reliability, better process accuracy, complex control algorithms, statistical process control and real time error checking. The analog control strategy was completely overwhelmed by these requirements and a new generation of digital controllers was born.

Figure 5 is a block diagram of the new EMR system. Inside of the EMR controller is a powerful programmable logic controller (PLC). The PLC receives analog feedback from the riveter through an analog to digital converter (A/D). As shown in Figure 5 the PLC receives feedback from the capacitor voltage which controls the charge energy. The PLC monitors the coil temperatures which allows for temperature compensation of the voltage compensate for the coil resistance. The PLC also monitors the pulse coil current which permits verification of the riveting pressure for each fastener. The PLC controls the EMR through discreet output as shown.

Establishing accurate analog communication with the cell controller has always been difficult. In many cases a differential voltage is required between the two EMR guns. In many cases it is desirable to slightly delay one EMR gun from the other. This requires the communication of three values with ten bit resolution for each, a total of thirty bits. A much simpler more effective way with the digital controller is to store the rivet energy and delay table inside the EMR controller rather than in the cell controller. A typical automatic riveting machine might be tooled to install as many as 64 different fasteners which requires a communication of just six bits from the cell controller.

Since the voltage table information is available in the digital memory of the PLC it is straightforward to compensate the voltage for coil temperature using digital logic. This is quite desireable in comparison with the analog multiply which was previously employed.

The cell controller indicates the fastener style and diameter to the EMR. The cell controller determines the clamp thickness and then chooses the fastener grip length. This information is also transferred across to the EMR controller. A typical I/O list between the cell controller and the EMR controller is provided in Table 1.

TABLE 1

DIGITAL INPUTS FROM THE CELL CONTROLLER

BITS	FUNCTION
1	Charge-dump
1	Fire
2	Fastener diameter code
4	Fastener grip length code
1	1st hit vs 2nd
1	Lockbolt vs rivet
10	TOTAL

DIGITAL OUTPUTS TO THE CELL CONTROLLER

BITS	FUNCTION
1	EMR on
1	Ready to fire
1	Fired ok
1	EMR error level 1 present
1	EMR error level 2 present
2	Fastener grip diameter code
4	Fastener grip length code
1	1st hit vs 2nd
1	Lockbolt vs rivet
13	TOTAL

Note that a full handshake of fastener information is provided in the I/O list.

An important enhancement provided for by the new controller is the complex error checking and reporting capability. Table 2 lists the 13 errors which are monitored by the digital controller.

Table 2

Error Codes

ERR #	ERROR
1, 2	The left (1) or right (2) current in the previous shot is too low
3, 4	The left (3) or right (4) current in the previous shot is too high
5, 6	The left (5) or right (6) coil temperature exceeds the maximum
7, 8	The left (7) or right (8) capacitor voltage has charged too high
9, 10	The left (9) or right (10) capacitor bank is slow to charge
11, 12	The left (11) or right (12) coil thermocouple is broken
13	Time-out, charge voltage held up longer than the allowed time

Of these 13 errors just 3 (numbers 5, 6 and 13) were supported by the previous generation analog controllers.

The front panel of the controller is shown in Figure 6 with the operator interface portion labeled in Figure 7. The digital controller is equipped with a front panel display with data entry and control push buttons. By following the menu the operator can assign a priority to each of these errors. The choice of priorities listed in Table 3 dictates the actions taken in response to an error.

TABLE 3

ERROR PRIORITY LEVELS

ERROR PRIORITY	ACTION
0	-ignore
1	-flash front display message one sec every ten sec -sound beeper one sec every ten sec -print out the error if concurrent with a fastener print code -indicate level 1 error to the cell controller
2	-inhibit EMR operation until manual reset -flash front display message -sound beeper -print level 2 error message -indicate level 2 error to the cell controller

A number of different screens are accessed through the arrow keys. Note for the screen in Figure 7 that the first line is the temperature compensated command voltage, the second line is the actual capacitor voltage, the third line is the coil current measured in the most recent shot.

An important feature is the data recording capability provided through the printer port. Each time the EMR fires the information in Table 4 is printed.

TABLE 4

FASTENER PRINTED RECORD

Time and date
Fastener type
Command voltage left and right
Actual voltage left and right at instant of firing
Delay time and delay side
Coil temperatures left and right
Peak coil currents left and right
Level 1 errors present
Level 2 errors are printed alone (riveting process terminated)

If preferred, the data string can be shipped to a hard drive. The printed message provides a permanent process record of the installed fastener. The digital control scheme has greatly improved process control of the riveting process. Many other processes will similarly benefit from dedicated computer control.

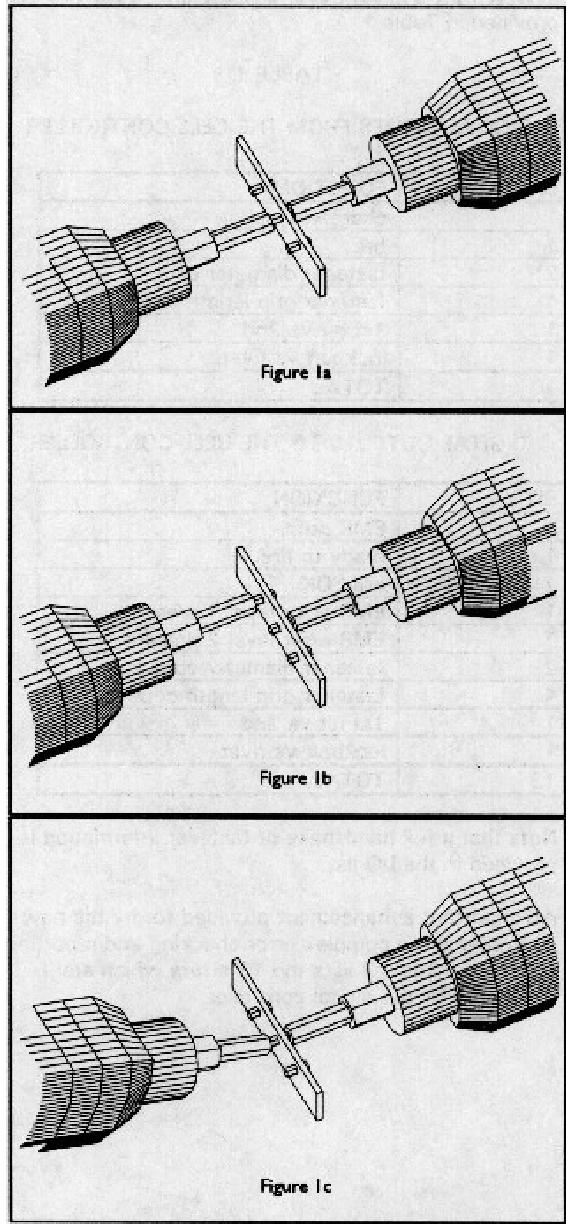

Figure 1 Proper (a) and incorrect alignment (b, c) of handheld EMRs

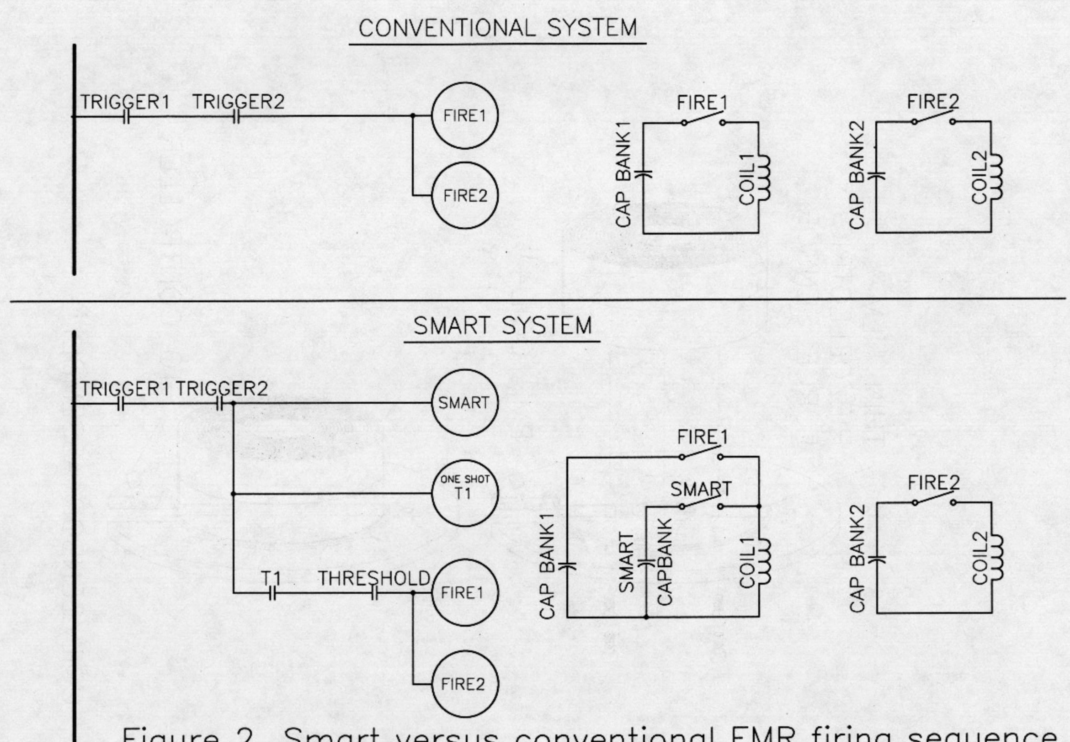

Figure 2 Smart versus conventional EMR firing sequence

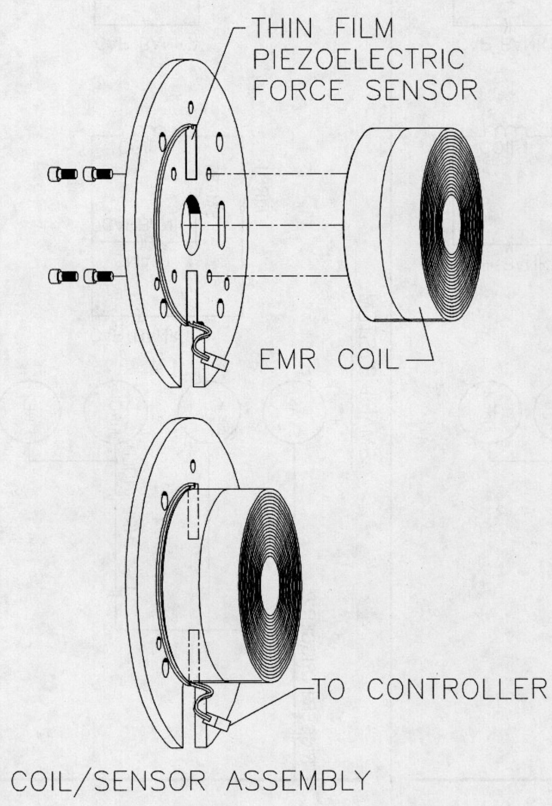

FIGURE 3

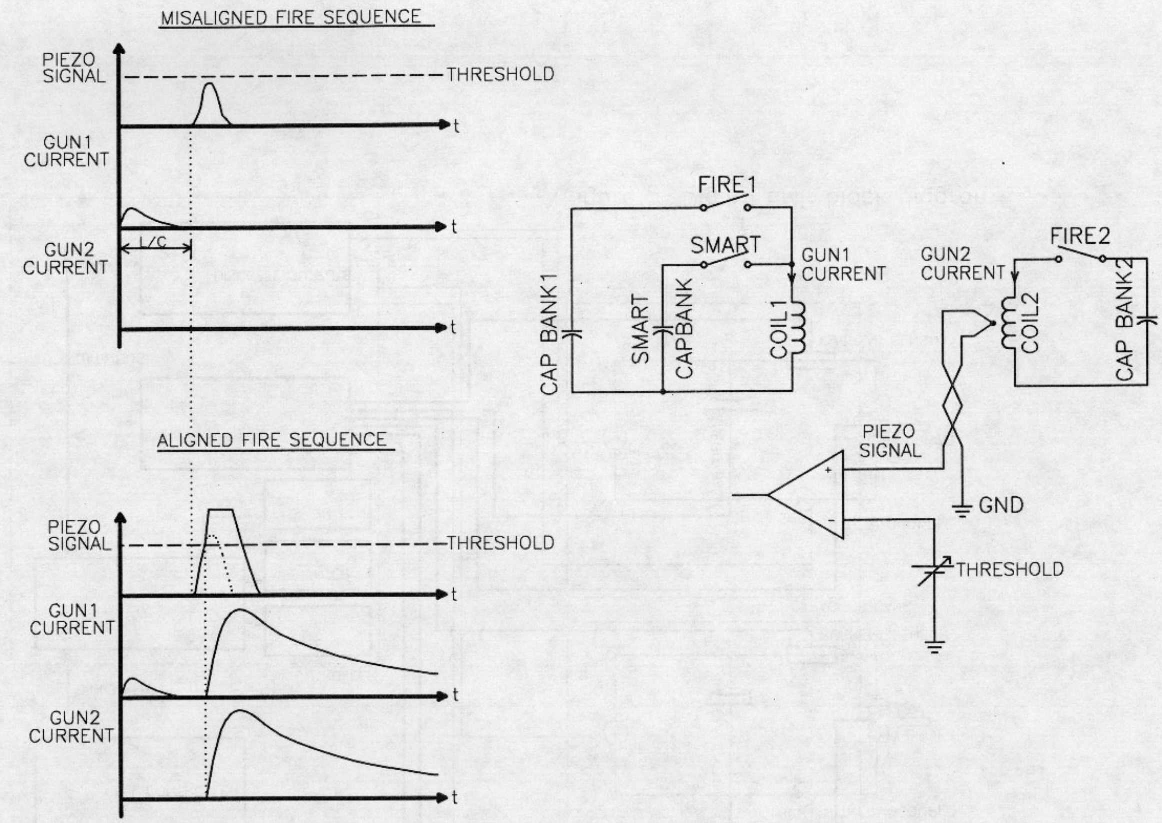

Figure 4 Misaligned and aligned signal output from smart sensor

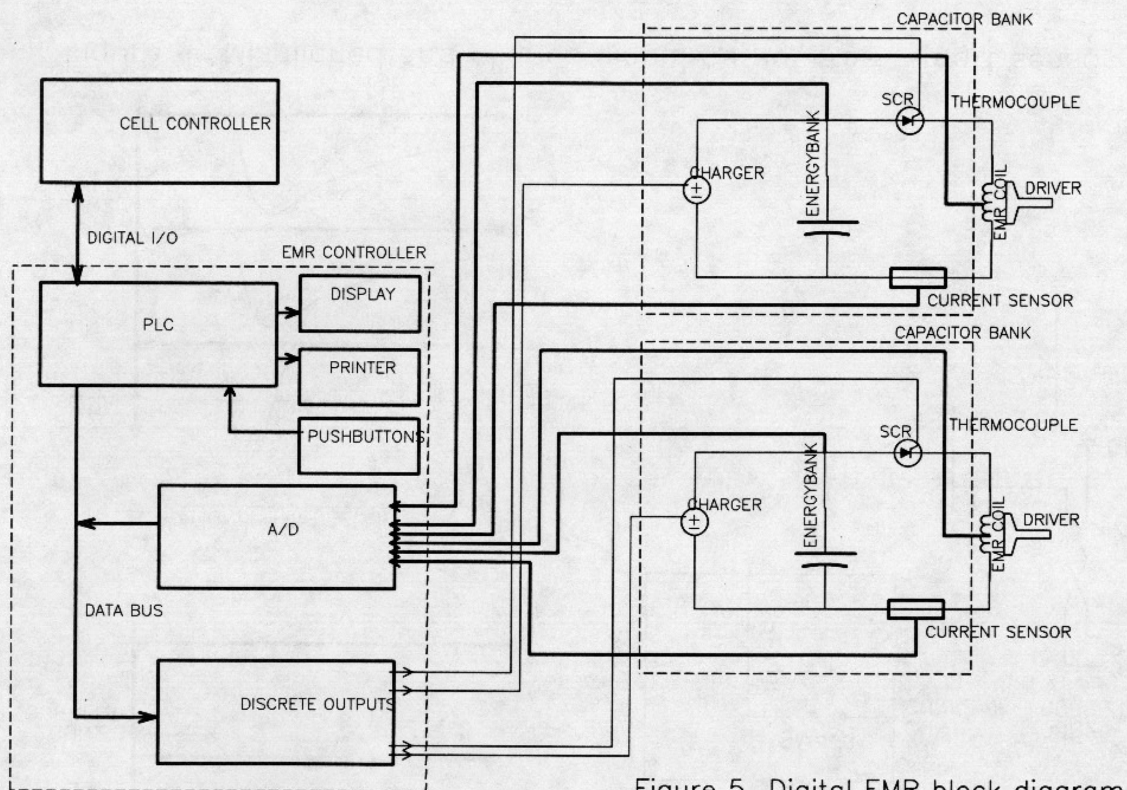

Figure 5 Digital EMR block diagram

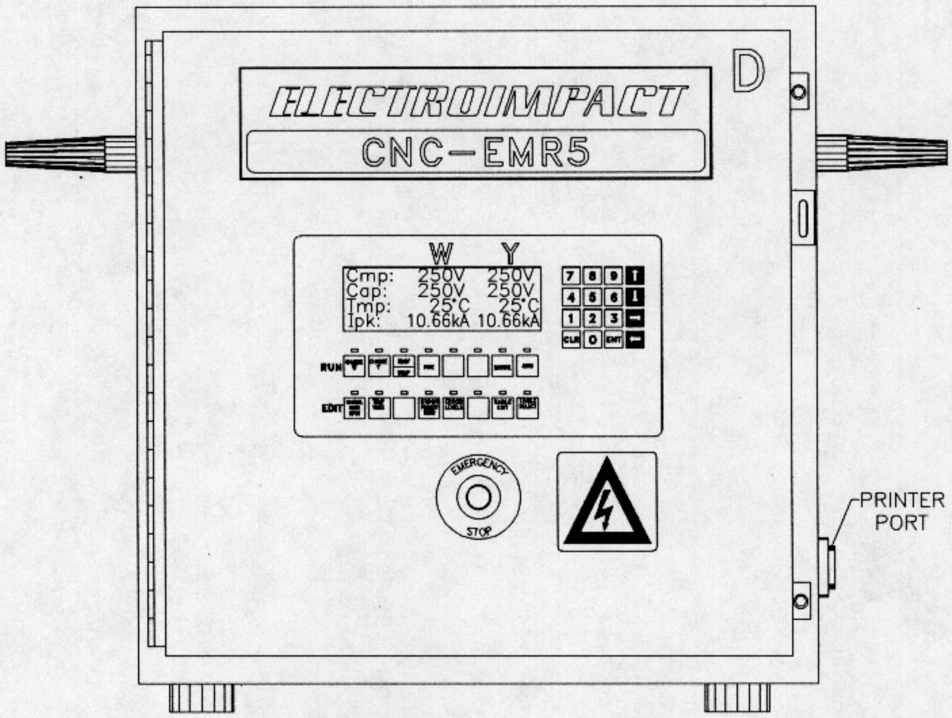

Figure 6. Digital EMR Enclosure

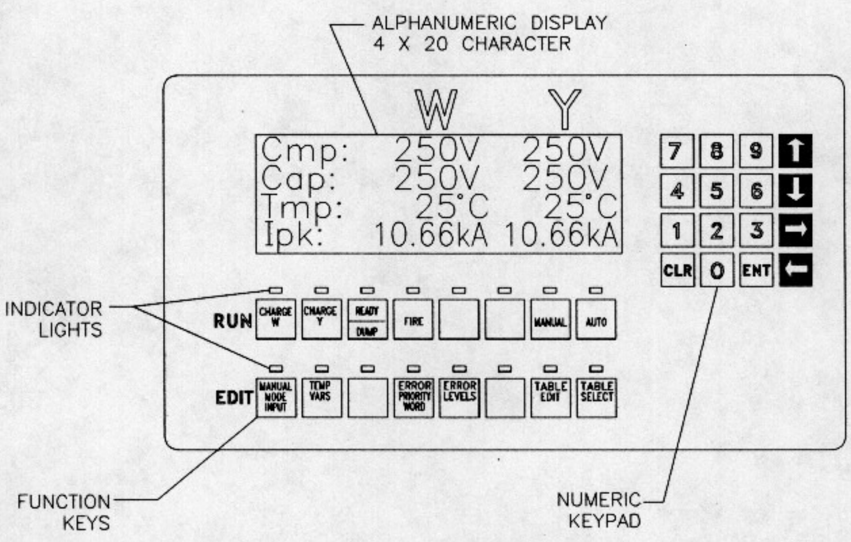

Figure 7. EMR Operator Interface