Appendix E
Power Requirements for Series Firing Circuits

E-1. Series Circuits. Electric blasting caps are connected in series and fried with an electric power source (blasting machine). A series circuit provides a single path for the electrical current that flows from one firing wire, through each blasting cap to the next blasting cap, and back to the other firing wire. A series circuit should not contain more than 50 blasting caps. The connection of more than 50 caps in a series circuit increases the chances of breaks in the firing line or cap leads.

E-2. Ohm's Law. *Ohm's Law* defines the amount of voltage necessary to detonate the blasting caps. Determine the required voltage for your firing circuit as follows:

$$E=IR \qquad \text{(E-1)}$$

where—

E = *electric potential, or voltage, in volts.*
I = *current, in amperes.*
R = *resistance, in ohms.*

E-3. Electric Power Formula. Determine the amount of electric power (watts) necessary to detonate blasting caps:

$$W= I^2R \qquad \text{(E-2)}$$

where—

W = electrical power, in watts.
I = *current, in amperes.*
R = *resistance, in ohms.*

E-4. Electric Blasting Caps. Military electric blasting caps connected in series require at least 1.5 amperes to fire, regardless of the number of caps in the series. The resistance of military electric blasting cap is 2 ohms.

E-5. Circuit Resistance. Ensure that the power source is adequate to fire all charges connected to the circuit. Firing wire, as well as blasting caps, contribute to total resistance in the circuit. Determine the amount of resistance by combining the individual resistances of the blasting caps and the wires. The resistance in the wire depends on the wire's size and length. Table E- 1 (page E-2) gives the resistance per 1,000 feet of various sizes of copper wire.

Table E-1. Resistance in copper wire

Wire Characteristics			Resistance per 1,000 Feet (Ohms)
AWG (B&S) Gauge No.	Diameter (In)	Weight (Lb/Ft)	
2	3/10	5.0	0.2
4	1/4	7.9	0.3
6	1/6	12.6	0.4
8	1/8	20.0	0.6
10	1/10	31.8	1.0
12	1/12	50.0	1.6
14	1/16	80.0	2.5
16	1/20	128.0	4.0
18	1/25	203.0	4.0
20	1/30	323.0	10.2
NOTE: For resistance, the ratings are for single-strand wire. Since blasting wire usually comes in double strands, use half its length to compute total resistance.			

E-6. Series Circuit Calculations. Complete calculations for any series circuit involved in determining the amount of current (amperes), voltage (volts), and power (watts) needed to fire the circuit. Use the following procedure:

a. *Current.* The current required for a series circuit of electric blasting caps is 1.5 amperes, regardless of the number of blasting caps in the circuit.

b. *Resistance.* Determine the resistance in the circuit (paragraph E-5, page E-l).

c. *Voltage.* Determine the required voltage for the circuit (paragraph E-2, page E- 1).

d. *Power.* Determine the required power for the circuit (paragraph E-3, page E-l).

e. *Example.* Determine the current, voltage, and power required to detonate a 20-cap series circuit consisting of special electric blasting caps and 500 feet of standard, 2-conductor, 18-gauge firing wire.

(1) Current. The amount of current required to detonate this circuit is 1.5 amperes

(2) Resistance.

Caps: 2.0 ohms (20 caps)= 40.0 ohms
Wire: 500 feet (2 strands)= 1,000 feet= 6.4 ohms (Table E-1)
Total Resistance: 46.4 ohms

NOTE: Number-18 wire consists of two strands. The example specifies a 500-foot piece of wire, so use 1,000 feet as the total wire length for determining resistance (500 x 2 = 1,000).

(3) Voltage.

$E = IR = 1.5(46.4) = 69.6$ *volts* (E-3)

where-

E = *voltage, in volts*
I = *current, in amperes*
R = *resistance, in ohms*

(4) Power.

$W = 1^2(R) = 1.5^2(46.4) = 104.4$ *WattS* (E-4)

where—

W = *power, in watts*
I = *current, in amperes*
R = *resistance, in ohms*

E-7. Voltage Drop. *Ohm's Law* allows you to determine the amount of voltage required (voltage drop) for a blasting circuit. In practice, the voltage drop should never exceed 90 percent of the available voltage; if it does, decrease the resistance or increase the voltage in the circuit to ensure that proper detonation occurs.

E-8. Blasting Machines. The name plate on power sources normally states the amperage and the voltage ratings. Before using any power source, determine whether it is suitable for your firing circuit. Generally, you can determine the adequacy of a power source by consulting Table E-2 (page E-4). This table lists the sizes of circuits that power sources can support. If you must determine the power source's capabilities from the name plate, use the following procedure:

a. *Determining Circuit Capacity*.

- Step 1. Multiply the power source's voltage rating by 90 percent to get an adjusted voltage rating.
- Step 2. Divide the adjusted voltage rating (Step 1) by the circuit's amperage rating (1.5 amperes). At this point you have the maximum allowable resistance in the circuit, in ohms.
- Step 3. Determine the total resistance from the firing wire (Table E-l).
- Step 4. Subtract the wire's resistance from the maximum allowable circuit resistance (Step 2) to determine the maximum allowable resistance of the blasting caps in the circuit.
- Step 5. Determine the maximum number of blasting caps the circuit will support by dividing the allowable resistance for caps (Step 4) by the resistance in one cap (2 ohms).

Table E-2. Power source capacities

Power Source	Circuit Size (Series)		
	10-Cap	30-Cap	50-Cap
Blasting Machine, 10-Cap	x	—	—
Blasting Machine, 30-Cap	x	x	—
Blasting Machine, 50-Cap	x	x	x
Generator, 1.5-kw, Portable (115V, 13.5A)	x	x	—
Generator, 3-kw, Portable (115V, 26A)	x	x	—
Generator, 5-kw, Portable (115V, 43.5A)	x	x	—
Generator, 3-kw, Portable (220V, 13.5A)	x	x	x
Generator, 5-kw, Portable (220V, 22.5A)	x	x	x

b. *Example.* Determine the maximum number of electric blasting caps allowed in a series circuit fired by a 220-volt, 13.5-ampere generator and 250 feet of double-strand, 20-gauge wire (a total of 500 feet of wire).

(1) Allowable Resistance.

$$\frac{0.90(220\ volts)}{1.5\ amperes} = 132\ ohms \qquad \text{(E-5)}$$

(2) Resistance in Firing Wire.

$$\frac{10.2\ ohms\ (500\ feet)}{1{,}000} = 5.2\ ohms \qquad \text{(E-6)}$$

(3) Allowable Resistance in Blasting Caps.

$$132\ ohms - 5.2\ Ohms = 126.8\ Ohms \qquad \text{(E-7)}$$

(4) Number of Blasting Caps.

$$\frac{126.8\ ohms}{2\ ohms} = 63.4\ caps\ (Round\ down\ to\ 63\ caps) \qquad \text{(E-8)}$$

E-9. Batteries and Dry Cells. Use the procedure in paragraph E-8 (page E-3) to determine the size of a circuit supported by a battery or dry cell.