Why Measure Soil Resistivity?

Soil resistivity measurements have a threefold purpose. First, such data is used to make sub-surface geophysical surveys as an aid in identifying ore locations, depth to bedrock and other geological phenomena. Second, resistivity has a direct impact on the degree of corrosion in underground pipelines. A decrease in resistivity relates to an increase in corrosion activity and therefore dictates the protective treatment to be used. Third, soil resistivity directly affects the design of a grounding system, and it is to that task that this discussion is directed. When designing an extensive grounding system, it is advisable to locate the area of lowest soil resistivity in order to achieve the most economical grounding installation.

Effects of Soil Resistivity on Ground Electrode Resistance

Soil resistivity is the key factor that determines what the resistance of a grounding electrode will be, and to what depth it must be driven to obtain low ground resistance. The resistivity of the soil varies widely throughout the world and changes seasonally. Soil resistivity is determined largely by its content of electrolytes, which consist of moisture, minerals and dissolved salts. A dry soil has high resistivity if it contains no soluble salts (Figure 1).

	Resistivity (approx), Ohm-centimeters		
SOIL	**MINIMUM**	**AVERAGE**	**MAXIMUM**
Ashes, cinders, brine, waste	590	2370	7000
Clay, shale, gumbo, loam	340	4060	16,300
Same, with varying proportions of sand and gravel	1020	15,800	135,000
Gravel, sand, stones with little clay or loam	59,000	94,000	458,000

Figure 1

Factors Affecting Soil Resistivity

Two samples of soil, when thoroughly dried, may in fact become very good insulators having a resistivity in excess of 10^9 ohm-centimeters. The resistivity of the soil sample is seen to change quite rapidly until approximately 20% or greater moisture content is reached (Figure 2).

Moisture content % by weight	Resistivity (Ohm-centimeters)	
	TOP SOIL	**SANDY LOAM**
0	$>10^9$	$>10^9$
2.5	250,000	150,000
5	165,000	43,000
10	53,000	18,500
15	19,000	10,500
20	12,000	6300
30	6400	4200

Figure 2

The resistivity of the soil is also influenced by temperature. Figure 3 shows the variation of the resistivity of sandy loam, containing 15.2% moisture, with temperature changes from 20° to -15°C. In this temperature range the resistivity is seen to vary from 7200 to 330,000 ohm-centimeters.

Temperature C	Temperature F	Resistivity (Ohm-centimeters)
20	68	7,200
10	50	9,900
0	32 (water)	13,800
0	32 (ice)	30,000
-5	23	79,000
-15	14	330,000

Figure 3

Because soil resistivity directly relates to moisture content and temperature, it is reasonable to assume that the resistance of any grounding system will vary throughout the different seasons of the year. Such variations are shown in Figure 4. Since both temperature and moisture content become more stable at greater distances below the surface of the earth, it follows that a grounding system, to be most effective at all times, should be constructed with the ground rod driven down a considerable distance below the surface of the earth. Best results are obtained if the ground rod reaches the water table.

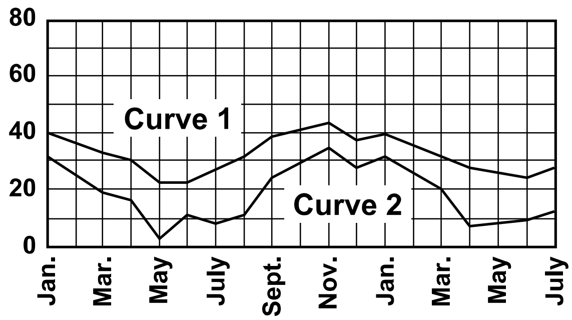

Figure 4

Seasonal variation of earth resistance with an electrode of 3/4-inch pipe in rather stony clay soil. Depth of electrode in earth is 3 ft. for Curve 1, and 10 ft. for Curve 2

In some locations, the resistivity of the earth is so high that low-resistance grounding can be obtained only at considerable expense and with an elaborate grounding system. In such situations, it may be economical to use a ground rod system of limited size and to reduce the ground resistivity by periodically increasing the soluble chemical content of the soil. Figure 5 shows the substantial reduction in resistivity of sandy loam brought about by an increase in chemical salt content.

THE EFFECT OF SALT* CONTENT ON THE RESISTIVITY OF SOIL (Sandy loam, Moisture content, 15% by weight, Temperature, 17°C)	
Added Salt (% By weight of moisture)	**Resistivity (Ohm-centimeters)**
0	10,700
0.1	1800
1.0	460
5	190
10	130
20	100

Figure 5

Chemically treated soil is also subject to considerable variation of resistivity with temperature changes, as shown in Figure 6. If salt treatment is employed, it is necessary to use ground rods, which will resist chemical corrosion.

THE EFFECT OF TEMPERATURE ON THE RESISTIVITY OF SOIL CONTAINING SALT (Sandy loam, 20% moisture, Salt 5% of weight of moisture)	
Temperature C	**Resistivity (Ohm-centimeters)**
20	110
10	142
1.00	190
-5	312
-13	1440

Figure 6

**Such as copper sulfate, sodium carbonate, and others*
Salts must be EPA or local ordinance approved prior to use.

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