Circular No. 19 1937

STATE OF ILLINOIS
HENRY HORNER, Governor

WATER QUALITY FOR FIRE FIGHTING

THE RELATION OF WATER RESISTIVITY TO SAFE DISTANCE FROM NOZZLE TO ELECTRIC LINES

★

DEPARTMENT OF REGISTRATION AND EDUCATION
J. J. HALLIHAN, Director

STATE WATER SURVEY DIVISION
URBANA, ILL

[Printed by authority of the State of Illinois.]

Circular No. 19

WATER QUALITY FOR FIRE FIGHTING

THE RELATION OF WATER RESISTIVITY TO SAFE DISTANCE FROM NOZZLE TO ELECTRIC LINES

BY

A. M. Buswell

and

W. V. Upton

Issued By

STATE WATER SURVEY DIVISION

A. M. BUSWELL, Chief

URBANA, ILL.

INTRODUCTION.

It is known that when, a fire hose is directed onto a high voltage power line the firemen are in danger of electrical shock. This circular has been prepared to aid fire departments in determining the safe distance from which a stream may be directed against a high voltage line. In preparing this material we are indebted to the Engineering Experiment Station of Purdue University for permission to use the results of certain important experiments carried out in their laboratory. The analyses of Illinois waters were obtained from the files of the Illinois State Water Survey.

Part I presents a technical discussion of the way in which calculations of resistivities have been made. This part is not necessary for the use of fire departments but is included for the benefit of those who might wish to make similar Calculations.

Part II shows a table from which the safe distance from the hose nozzle to a power line can be determined if the resistivity of the water and the power line voltage are known.

It also contains an alphabetical list of most of the towns in Illinois with the resistivity of the water from the public supply. Where a town has been omitted it is because the character of the water was not definitely known. The State Water Survey will be glad to supply this information through correspondence.

The "safe distance" values given in Part II are based on the fact that normal persons can stand three milliamperes without experiencing any real discomfort. Firemen should try a three milliampere shock so that they will know what to expect if they find it necessary to play a hose on a power line.

PART I.

TECHNICAL DISCUSSION.

As mentioned above it has been pointed out by Sprague and Harding of the Purdue University Engineering Experiment Station* that, since the mineral or salt content of water greatly affects its ability to conduct electricity, the safety of firemen working in the vicinity of electric lines depends to some extent upon the chemical quality of the water they use. These investigators have experimentally determined the minimum safe distances for firemen to stand using fire streams of water with a given resistance from transmission lines carrying electricity at various voltages. They also obtained values for the electrical resistivity of several Indiana city waters experimentally. We are able to calculate the resistivity of waters from Illinois municipal supplies from analyses in the files of the State Water Survey. Benefiting from the data of Sprague and Harding we have obtained reasonably accurate values for the minimum safe distances from nozzle to power line.

The value for the specific conductance for a solution of an electrolyte may be obtained from the formula

$$(1) \quad K = C \ (m_c + m_a)$$

where K is the specific conductivity in reciprocal ohms per cubic centimeter, C is the concentration of the salt in equivalents per cubic centimeter and m_c and m_a are the mobilities of the cation and anion respectively. Since the resistivity is the reciprocal of the specific conductivity, equation (1) may be written

$$(2) \quad 1/R = C \ (m_c + m_a), \text{ or}$$

$$(3) \quad R = \frac{1}{C \ (m_c + m_a)}$$

where R is the resistivity of the solution in ohms per cubic centimeter.

Values for the mobilities of ions commonly present in water are:

Cations		*Anions*	
Sodium	43.4	Chloride	65.5
Potassium	64.6	Carbonate	60.0
Calcium	51.9	Sulfate	68.5
Magnesium	45.9	Nitrate	61.8
Ammonium	64.7		

In order to simplify the calculation of resistivities it was decided to select an average value for the mobility of cations and one for the mobility of anions. Consideration of the ions generally present in largest amounts

* Purdue University Engineering Experiment Station Bulletin, Research Series No. 53.

in Illinois waters led to the somewhat empirical choices of 50 for the average cation mobility and of G5 for the average anion mobility.

The resistivities of waters in Illinois municipal supplies listed in Table II were calculated using equation (3) with the above average mobility values and with values for salt concentrations in waters obtained from analyses made by the State Water Survey. Using these resistivities the minimum distances from power lines at which fire hose can safely be used may be obtained from Table I

In order to obtain some idea of the resistivity of a water when neither a complete knowledge of its mineral content nor apparatus for making conductivity tests are available, a rough method has been worked put. The residues from evaporation of samples of Illinois waters (expressed in milligrams of residue per liter of water) were multiplied by the calculated resistivities of these waters. On the basis of these comparisons the following equation has been obtained.

$$(4) \quad \text{Resistivity} = \frac{400{,}000}{\text{Residue}}$$

Resistivity values obtained by use of this formula will be only approximate but any error will be toward greater safety, in a few cases as much as fifty per cent. Expressed in feet the maximum error will be only four feet added to the minimum safe distance from nozzle to electric line.

PART II.

CALCULATION OF "SAFE DISTANCE"

The "safe distance" from hose nozzle to an electric line has been figured from the fact that normal persons do not suffer any real discomfort from a three milliampere current. The current which will flow down the hose stream will depend on the voltage of the electric line and the resistivity of the water. The nozzle size and nozzle pressure have small effects on the amperage of the current but these effects are too small to require consideration in the calculations.

Table I gives the safe distances in feet from the nozzle to the electric line for various voltages and various water resistivities. This table is reproduced by permission from a bulletin published by Purdue University.

Table II is an alphabetical list of towns in Illinois showing the resistivity of the water from the public supply. A few towns have been omitted. The State Water Survey will be glad to supply information on these towns by correspondence.

To use these tables look up your town in Table II and note the resistivity. Then find out from the power company the voltage carried on its line or lines. Next turning to the table draw a line down from the resistivity and across from the voltage. The number where these lines intersect is the safe nozzle distance in feet.

Example 1. Aurora resistivity 940. Choose the next higher column, namely, 1000. For voltages from 440 to 4400 the safe distances are from *7* feet to 35 feet. For higher voltages there is no safe distance. (See foot note).

Example 2. Avon resistivity 220, no safe distance can be recommended from present data.

TABLE I.

SAFE DISTANCES FROM HIGH POTENTIAL, LINES.**

Nozzle pressure, 50 pounds per sq. in.
Nozzle size, 1¼ inches.

Minimum Safe Distances for Given Resistivity in Feet.

Volts.	Resistivities.							
	500	1000	1500	2000	3000	4000	5000	6000
440	11	7	5.5	4.5	3.	3.	3.	3.
1,100	30	18	14.	12.	8.5	6.5	5.5	5.
2,200	*	30	23.	20.	15.	12.	9.	8.
4,400	*	35	31.	28.	23.	19.	16.	15.
6,600	*	*	34.	33.	30.	26.	23.	22.
13,200	*	*	*	*	33.	31.	29.	28.
22,000	*	*	*	*	*	*	*	*

* At these resistivities, for the respective voltages, and for all voltage above 13,200 volts, the fire stream should not be allowed to strike the line.

** Copied from Engineering Bulletin Purdue University, Research Series No. 53, with the permission of the Director.

TABLE II.

	Resistivity		Resistivity
Abingdon	550 ohm/cc	Byron	1500 ohm/cc
Addison	1050	Cabery	290
Aledo	320	Cairo	3900
Alexis	470	Calumet City	3370
Algonquin	1410	Cambridge	530
Alpha	550	Campus	770
Altamont	1000	Canton	210
Alton	1230	Capron	1380
Amboy	1030	Carbon Hill	430
Anna	1430	Carbondale	2180
Antioch	1610	Carlinville	1280
Arcola	730	Carpentersville	1020
Arlington	1140	Carrolton	1340
Arlington Heights	870	Cary Station	1330
Arthur	230	Casey	920
Ashland	770	Catlin	1000
Ashton	1220	Cedar Point	510
Assumption	1040	Centralia	300
Athens	760	Central City	300
Atkinson	780	Cerro Gordo	800
Atlanta	850	Chadwick	980
Atwood	940	Champaign	1230
Aurora	940	Chandlerville	840
Avon	220	Charleston	1520
Harrington	1160	Chatsworth	820
Barry	1620	Chenoa	370
Bartlett	560	Cherry	770
Batavia	1610	Chester	1230
Beardstown	1010	Chicago	3370
Beecher City	780	Chicago Heights	570
Belleville	1230	Chilicothe	940
Bellwood	800	Chrisman	740
Belvidere	890	Cicero	3370
Bement	320	Clarendon Hills	810
Bensenville	1140	Clay City	340
Benson	1450	Clinton	170
Berwyn	3370	Coal City	370
Bethany	980	Cobden	1640
Biggsville	770	Colchester	900
Blandinsville	230	Colfax	630
Bloomington	4920	Collinsville	1210
Blue Island	3370	Compton	1670
Blue Mound	1320	Creston	1710
Bluffs	680	Crescent City	1210
Bourbonnais	940	Crete	1160
Bradford	370	Crystal Lake	1100
Bradley	640	Cuba	230
Braidwood	1200	Cullom	220
Broadview	3370	Dallas City	1230
Brookfield	750	Danforth	500
Brooklyn	1230	Danvers	840
Brookport	2130	Danville	1640
Buckley	510	Decatur	3320
Buda	440	Deerfield	3370
Bulpitt	700	DeKalb	1410
Buncombe	1540	Deland	550
Bureau	480	DePue	950
Burnham	3370	Desplaines	320
Burr Oak	3370	Dixon	1420
Bushnell	300	Dolton	3370

	Resistivity
Dongola	1430 ohm/cc
Downers Grove	860
Duquoin	490
Dwight	510
Earlville	1670
East Alton	1350
East Dubuque	1390
East Dundee	980
East Lynn	730
East Moline	480
East Peoria	1530
East St. Louis	1230
Edwardsville	2070
Elburn	1220
Eldorado	8670
Elgin	1000
Elizabeth	890
Elmwood	370
El Paso	1010
Emington	830
Enfield	750
Erie	1510
Eureka	1060
Evanston	3370
Ewing	560
Pairbury	1210
Parmer City	670
Farmersville	1900
Farmington	320
Pieldon	810
Pindlay	740
Fisher	1360
Flanagan	810
Flat Rock	700
Flossmoor	730
Forrest	1240
Forreston	830
Fox Lake	1320
Fox River Grove	1170
Frankfort	940
Franklin Grove	940
Franklin Park	830
Freeport	980
Fulton	1340
Galena	1640
Galesburg	340
Galva	570
Geneseo	820
Geneva	1260
Genoa	1210
Georgetown	1460
Germantown	490
Gibson	1280
Gillespie	2500
Gilman	550
Glasford	320
Glencoe	3370
Glen Ellyn	1110
Glen View	900
Grand Ridge	1440
Grant Park	940
Granite City	1230
Granville	520 ohm/cc
Grays Lake	1320
Grayville	1500
Greenfield	700
Greenup	1320
Greenview	670
Greenville	740
Gridley	760
Griggsville	1430
Hamilton	1230
Hammond	820
Hampshire	1660
Hanover	1860
Hardin	670
Harmon	2170
Hartford	1130
Harvard	930
Harvey	3370
Havana	2440
Hebron	1810
Hennepin	520
Henry	1020
Heyworth	1210
Highland	1500
Highland Park	3370
Highwood	3370
Hillsboro	1610
Hinckley	1350
Hinsdale	1980
Homewood	630
Hoopeston	1270
Hopedale	1160
Hull	1440
Huntley	1180
Hutsonville	1670
Illiopolis	890
Ipava	180
Itasca	1030
Jacksonville	1560
Jerseyville	1310
Joliet	800
Jonesboro	1110
Joy	920
Kankakee	1490
Kansas	1230
Keithsburg	560
Kempton	590
Kenilworth	3370
Kewanee	260
Kincaid	700
Kinsman	580
Kirkwood	920
Knoxville	480
Lacon	970
Ladd	1280
LaGrange	610
LaHarpe	830
Lake Bluff	1630
Lake Forest	3120
Lake Zurich	360
LaMoille	1450
Lanark	1340

	Resistivity
LaSalle	1180 ohm/cc
Lawrenceville	2040
Leaf River	1630
Lebanon	880
Lee	1770
Leland	1320
Lemont	560
Lena	890
Leonore	1130
Leroy	870
Lewistown	1110
Lexington	1150
Libertyville	860
Lincoln	1570
Litchfield	1600
Little York	350
Lockport	380
Lombard	1260
Lostant	950
Lovington	820
Lyons	630
Mackinaw	780
Macomb	1880
Macon	500
Madison	1230
Mahomet	780
Malta	1810
Manhattan	1070
Manlius	1020
Manteno	720
Maple Park	1550
Marengo	1150
Marissa	860
Maroa	1050
Marseilles	990
Marshall	1850
Martinsville	950
Mason City	1700
Matteson	720
Mattoon	2320
Maywood	720
McHenry	1450
McLean	870
Melrose Park	790
Melvin	1040
Mendota	1230
Metamora	790
Metropolis	2120
Milan	500
Milford	800
Milledgeville	1320
Millstadt	1230
Minier	1340
Minonk	660
Minooka	660
Mokena	780
Moline	1230
Momence	1020
Monee	800
Monmouth	520
Montgomery	450
Monticello	1300
Morris	1060 ohm/cc
Morrison	1540
Morrisonville	1310
Morton	970
Morton Grove	930
Mound City	1770
Mounds	1940
Mount Carmel	1240
Mount Carroll	1230
Mount Greenwood	3370
Mount Morris	1310
Mount Prospect	940
Mount Pulaski	870
Mount Sterling	430
Mount Vernon	1790
Moweaqua	1420
Mundelein	1610
Naperville	1070
National City	1230
Nauvoo	1230
Neoga	830
New Baden	360
New Holland	950
Newman	430
Niles	3370
Niles Center	3370
Nokomis	590
Normal	1120
Norris City	670
Northbrook	580
North Chicago	940
North Utica	810
Oaklawn	380
Oak Park	3370
Oakland	1000
Oblong	2020
Odell	300
Oglesby	590
Ohio	1580
Okawville	860
Olney	5470
Onarga	610
Oquawka	1760
Oregon	970
Orion	970
Orland Park	810
Oswego	980
Ottawa	1120
Palatine	760
Palestine	2020
Pana	3300
Paris	1560
Park Ridge	3370
Paw Paw	1740
Paxton	1000
Pearl	2480
Pearl City	1000
Pecatonica	1400
Pekin	1020
Peoria	1330
Peoria Heights	920
Peotone	900

	Resistivity
Percy	1510 ohm/cc
Peru	210
Petersburg	630
Pinckneyville	1130
Piper City	1100
Pittsfield	3640
Piano	1500
Pleasant Hill	1790
Polo	1400
Pontiac	1330
Poplar Grove	1340
Princeton	1330
Prophetstown	1550
Quincy	1950
Ramsey	720
Rankin	1130
Ransom	570
Rantoul	1010
Raymond	1220
Red Bud	1410
Ridgefarm	1320
Riverdale	3370
River Forest	770
Riverside	680
Roberts	780
Robinson	2020
Rochelle	1550
Rockdale	850
Rockford	970
Rock Island	450
Rockton	1450
Roodhouse	1200
Roselle	1080
Roseville	2110
Rosiclare	3840
Rossville	1120
Round Lake	1290
Roxana	1280
Rushville	1200
Saint Anne	800
Saint Charles	1000
Saint Francisville	1540
Salem	3260
Sandwich	1270
Saunemin	180
Savannah	1520
Saybrook	1120
Schiller Park	710
Seaton	820
Secor	780
Seneca	720
Shabbona	1180
Shannon	1140
Shawneetown	1370
Sheffield	1020
Shelbyville	1220
Sheldon	850
Sibley	1460
Silvis	300
Somonauk	1530
South Chicago Heights	1050
South Jacksonville	1560

	Resistivity
South Pekin	1000 ohm/cc
Sparland	630
Sparta	250
Spring Valley	680
Standard	480
Stanford	790
Staunton	1880
Steeleville	1280
Steger	1130
Sterling	1340
Steward	1570
Stockton	1120
Stonington	1120
Strawn	1030
Streator	1160
Stronghurst	230
Sublette	1930
Sullivan	1200
Sycamore	1220
Tampico	1230
Taylorville	700
Thebes	1230
Thomson	3340
Thornton	880
Tinley Park	890
Tiskilwa	1500
Toledo	940
Tolono	640
Toluca	300
Toulon	490
Tremont	1020
Trenton	450
Troy	620
Tuscola	500
Union	1850
Vandalia	1530
Venice	1230
Vienna	530
Villa Grove	960
Villa Park	1090
Viola	480
Virginia	2040
Walnut	1500
Warren	1010
Warrensburg	820
Warsaw	1670
Washington	1200
Waterman	1360
Watseka	1450
Wauconda	1080
Waukegan	3030
Waynesville	850
Weldon	1110
Wenona	352
West Brooklyn	1260
West Chicago	1020
West Dundee	1310
Western Springs	450
Westfield	1230
West Frankfort	4720
Westmont	770
Wheaton	1400

	Resistivity
Wheeling	1340 ohm/cc
White Hall	3450
Williamsville	1160
Wilmette	3150
Wilmington	470
Winchester	1470
Windsor	910
Winfield	750
Winnetka	3370
Winslow	1390
Winthrop Harbor	1970 ohm/cc
Witt	1180
Woodhull	570
Wood River	1330
Woodstock	1130
Wyanet	990
Wyoming	550
Yorkville	1720
Zion City	900