

available liquids from this viewpoint, glycerol and sucrose solutions have too high a surface tension, and ethyl alcohol solutions are to be preferred on this account. The surface tension of water is also too high, but water would be excluded on other grounds, even if it were possible to reduce its surface tension without materially changing its viscosity. The viscosity of water is so low that the flow is turbulent, resulting in a change in the constants of formulas like Eqs. 1, 2 and 3.

It has previously been impossible to determine whether a Saybolt Universal Viscosimeter gave normal readings, as neither the dimensions, nor normal times of flow for any given liquids were known. Now that these data have been determined, limit gages have been prepared, and the Bureau of Standards is now in a position to certify whether or not a given instrument is of standard dimensions.

GROUND CONNECTIONS FOR ELECTRICAL SYSTEMS.*

By Orville S. Peters.

AN investigation of methods of grounding to protect persons from dangers associated with electrical circuits has recently been completed by the Bureau of Standards. The results are to be published in more extended form in a Technologic Paper. The investigation was undertaken in view of the fact that some of the methods of grounding now in use have in many cases proved unsatisfactory, and also that the information heretofore available on the subject is scattered through technical journals and reports and is consequently more or less inaccessible to those most interested in it.

Dangers to persons from electrical systems arise because of the occasional entrance of abnormally high voltage upon the low voltage parts of electrical circuits and equipment, to which persons have access, through faults in insulation between high-voltage and low-voltage circuits. Such faults are developed for the most part by lightning and breakage of wires in storms, and occasionally by high voltage singes or deteriorated insulation.

The magnitude of the potential differences which may appear between low-voltage circuits or parts of equipment and ground is governed by a number of factors, but chiefly by the voltage of the line with which contact is made and the relative location of the

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point of failure. For instance, with a 2200-volt a.c. distribution circuit feeding a low-voltage lighting circuit through a step-down transformer, a failure of insulation at an end turn of the high voltage winding may raise the potential difference between the lighting circuit and ground to a value approaching 2200 volts unless provision is made with a view to preventing it. A similar condition may arise with any low-voltage circuit if it makes contact with a high-voltage circuit.

Danger from high potentials between low-voltage circuits or parts of equipment and ground can best be averted by grounding the parts affected. For a high degree of safety to life the resistance of the ground connection should be such that with a current flow equal to the rated current of the nearest circuit breaker which will operate to disconnect the equipment or circuit concerned from the source of the dangerous voltage in the event of an accident to insulation, the potential difference between grounded wire and ground will not exceed 150 volts, if the grounded wire, or parts of equipment connected with it, is accessible. If the latter are inaccessible a higher voltage limit is permissible.

Water pipes offer by far the most desirable means of making ground connections, but where it is necessary to resort to other means, such as driven pipes or plates, an appreciable degree of protection can in some places be obtained at reasonable expense. In a great many cases, however, grounds of the latter type will be found unsatisfactory. If a common ground wire is used, a good degree of protection can be had, but the expense may be considerable, and the result not equal to that obtainable from water pipes, unless the common ground wire is connected to a water pipe.

The resistance of water pipe ground connections, where there are no high resistance joints nearby, averages about 0.25 ohm, which is sufficiently low for practical purposes in any case that is likely to arise. The resistance of driven pipe and plate grounds, however, is much higher than that of water pipe grounds. A series of measurements on ground connections made with driven pipes, plates, coils of wire and patented devices showed results as given in the accompanying table. These ground connections were found in service in a number of cities located in different parts of the United States between the Atlantic Coast and the Rocky Mountains.

RESISTANCE BY KINDS OF SOIL.

Number of grounds tested	Soil	Average Resist.	Minimum Resist.	Maximum Resist.
24	Fills, and ground containing more or less refuse, such as ashes, cinders, and brine waste.	14	3.5	41
205	Clay, shale, adobe, gumbo, loam, and slightly sandy loam with no stones or gravel.	24	2.0	98
237	Clay, adobe, gumbo, and loam mixed with varying proportions of sand, gravel and stones.	93	6	800
72	Gravel, sand and stones with little or no clay or loam.	554	35	2700

From these measurements it is readily seen that except in certain localities where natural conditions are particularly favorable towards making ground connections with driven pipes or plates, to obtain a degree of safety equal to that obtained with water pipes would entail an expense that would be almost prohibitive. It is possible, of course, to obtain an appreciable degree of protection with driven pipes in nearly all places, but the comparative advantages in connecting to water pipes are so great that the latter should be used wherever they are available.

Municipalities and water companies are urged to permit the connection of electrical circuits to their water pipes, especially from the point of view of safety to the public. There is, moreover, no possibility of damage to the pipes from currents flowing in them, nor of danger to employees of the pipe owning company, if simple precautions are observed in regard to the use of the pipes for the purpose of grounding.

TESTS OF LARGE BRIDGE COLUMNS.*

By J. H. Griffith and J. G. Bragg.

[ABSTRACT.]

Nature of Investigation.—Tests were made upon eighteen large bridge columns which were half size models of chord sections of railroad bridges recently erected at St. Louis, Mo., Metropolis,

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