Designation: D6820 – 18

Standard Guide for Use of the Time Domain Electromagnetic Method for Subsurface Site Characterization[1]

This standard is issued under the fixed designation D6820; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 *Purpose and Application:*

1.1.1 This guide summarizes the equipment, field procedures, and interpretation methods for the assessment of subsurface materials and their pore fluids using the Time Domain Electromagnetic (TDEM) method. This method is also known as the Transient Electromagnetic (TEM) Method, and in this guide is referred to as the TDEM/TEM method. Time Domain and Transient refer to the measurement of a time-varying induced electromagnetic field.

1.1.2 The TDEM/TEM method is applicable to the subsurface site characterization for a wide range of conditions. TDEM/TEM methods measure variations in the electrical resistivity (or the reciprocal, the electrical conductivity) of the subsurface soil or rock caused by both lateral and vertical variations in various physical properties of the soil or rock. By measuring both lateral and vertical changes in resistivity, variations in subsurface conditions can be determined.

1.1.3 Electromagnetic measurements of resistivity as described in this guide are applied in geologic studies, geotechnical studies, hydrologic site characterizations, and for mapping subsurface conditions at waste disposal sites (**1**).[2] Resistivity measurements can be used to map geologic changes such as lithology, geological structure, fractures, stratigraphy, and depth to bedrock. In addition, measurement of resistivity can be applied to hydrologic site characterizations such as the depth to water table, depth to aquitard, presence of coastal or inland groundwater salinity, and for the direct exploration for groundwater.

1.1.4 This standard does not address the use of TDEM/TEM method for use as metal detectors or their use in unexploded ordnance (UXO) detection and characterization. While many of the principles apply the data acquisition and interpretation differ from those set forth in this standard guide.

1.1.5 General references for the use of the method are McNeill (**2**), Kearey and Brooks (**3**), and Telford et al (**4**).

1.2 *Limitations:*

1.2.1 This guide provides an overview of the TDEM/TEM method. It does not provide or address the details of the theory, field procedures, or interpretation of the data. Numerous references are included for that purpose and are considered an essential part of this guide. It is recommended that the user of the TDEM/TEM method be familiar with the references cited and with the ASTM standards D420, D653, D5088, D5608, D5730, D5753, D6235, D6429 and D6431.

1.2.2 This guide is limited to TDEM/TEM measurements made on land. The TDEM/TEM method can be adapted for a number of special uses on land, water, ice, within a borehole, and airborne. Special TDEM/TEM configurations are used for metal and unexploded ordnance detection. These TDEM/TEM methods are not discussed in this guide.

1.2.3 The approaches suggested in this guide for the TDEM/TEM method are commonly used, widely accepted, and proven. However, other approaches or modifications to the TDEM/TEM method that are technically sound may be substituted.

1.2.4 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education, experience, and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word standard in the title of this document means only that the document has been approved through the ASTM consensus process.*

1.3 *Precautions:*

1.3.1 It is the responsibility of the user of this guide to follow any precautions in the equipment manufacturer's recommendations and to establish appropriate health and safety practices.

1.3.2 If the method is used at sites with hazardous materials, operations, or equipment, it is the responsibility of the user of

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

*A Summary of Changes section appears at the end of this standard this guide to establish appropriate safety and health practices and to determine the applicability of any regulations prior to use.

1.3.3 This guide does not purport to address all of the safety concerns that may be associated with the use of the TDEM/TEM method. It must be emphasized that potentially lethal voltages exist at the output terminals of many TDEM/TEM transmitters, and also across the transmitter loop, which is sometimes uninsulated. It is the responsibility of the user of this equipment to assess potential environmental safety hazards resulting from the use of the selected equipment, establish appropriate safety practices and to determine the applicability of regulations prior to use.

1.3.4 *Units*—The values stated in SI units are regarded as standard. No other units of measurement are included in this standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this guide.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D420 Guide to Site Characterization for Engineering Design and Construction Purposes

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D5088 Practice for Decontamination of Field Equipment Used at Waste Sites

D5608 Practices for Decontamination of Sampling and Non Sample Contacting Equipment Used at Low Level Radioactive Waste Sites

D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Groundwater (Withdrawn 2013)[4]

D5753 Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging

D6235 Practice for Expedited Site Characterization of Vadose Zone and Groundwater Contamination at Hazardous Waste Contaminated Sites

D6429 Guide for Selecting Surface Geophysical Methods

D6431 Guide for Using the Direct Current Resistivity Method for Subsurface Investigation

D6639 Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Site Characterizations

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.1.2 The majority of the technical terms used in this document are defined in Sheriff (**5**) and Bates and Jackson (**6**).

4. Summary of Guide

4.1 *Summary*—A typical TDEM/TEM survey configuration for resistivity sounding (Fig. 1) consists of a transmitter connected to a (usually single-turn) square loop of wire (generally but not necessarily insulated), laid on the ground. A multi-turn receiver coil, usually located at the center of the transmitter loop, is connected to a receiver through a short length of cable. In some scenarios, it is advantageous to also measure the horizontal component(s) (called Hx and Hy) of the received signal. In addition, depending upon the project goals, measurements may be made both inside and outside of the transmitter loop, sometimes called a 'fixed-loop array.'

4.1.1 The transmitter current waveform is usually a periodic, symmetrical square wave (Fig. 2). After every second quarter-period the transmitter current (typically between 1 and 40 amps) is abruptly reduced to zero for one quarter period, after which it flows in the opposite direction to the previous flow.

4.1.2 Other TDEM/TEM configurations use triangular wave current waveforms and measure the time-varying magnetic field while the current is on.

4.1.3 The process of abruptly reducing the transmitter current to zero induces, in accord with Faraday's Law, a short-duration voltage pulse in the ground that causes a current to flow in the vicinity of the transmitter wire (Fig. 3). After the transmitter current is abruptly turned off, the current loop can be thought of as an image, just below the surface of the ground, of the transmitter loop. However, because of the resistivity of the ground, the magnitude of the current flow immediately decays. This decaying current induces a voltage pulse in the

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

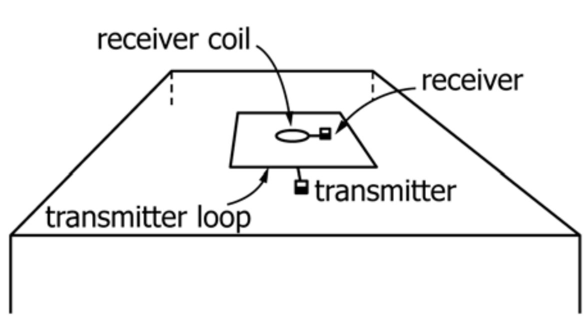

FIG. 1 Typical TDEM/TEM Survey Configuration (7)

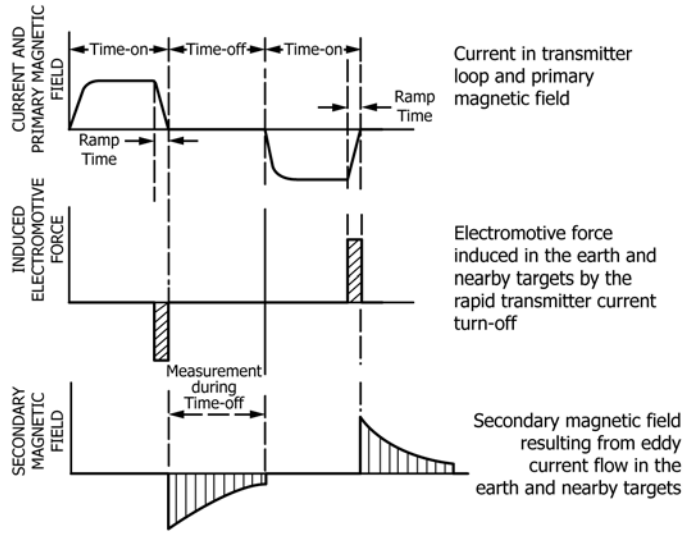

FIG. 2 Typical Time Domain Electromagnetic Waveforms (2)

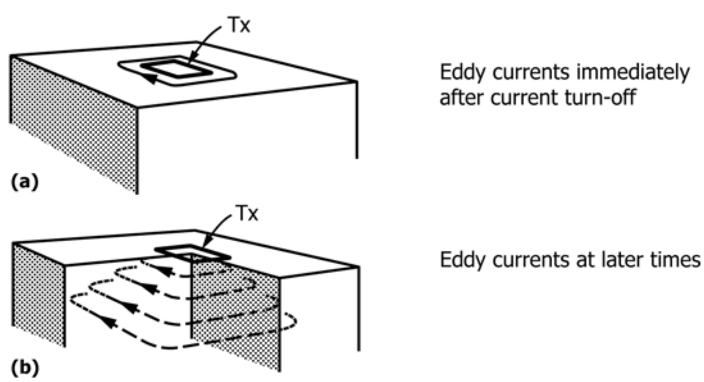

FIG. 3 Time Domain Electromagnetic Eddy Current Flow at (a) Early Time and (b) Late Time (2)

ground, which causes more current to flow at larger distances from the transmitter loop and at greater depths (Fig. 3). The deeper current flow also decays, due to the resistivity of the ground, inducing even deeper current flow. To determine the resistivity as a function of depth, the magnitude of the current flow in the ground as a function of time is determined by measuring the voltage induced in the receiver coil. The voltage is proportional to the time rate of change of the magnetic field arising from the subsurface current flow. The magnetic field is directly proportional to the magnitude of the subsurface current. By measuring the receiver coil voltage at successively later times, measurement is effectively made of the current flow, and thus the electrical resistivity of the earth, at successively greater depths.

4.1.4 Data resulting from a TDEM/TEM sounding consist of a curve of receiver coil output voltage as a function of time. Analysis of this curve produces a layered earth model of the variation of earth resistivity as a function of depth. The analysis can be done graphically or with commercially available TDEM/TEM data inversion programs.

4.1.5 To determine lateral variations of resistivity in the subsurface, both transmitter and receiver are moved along profile lines on a survey grid. In this way, a three-dimensional picture of the terrain resistivity is developed.

4.1.6 TDEM/TEM surveys for geologic, engineering, hydrologic and environmental applications are carried out to determine depths of layers or lateral changes in geological conditions to a depth of tens of meters. Using larger transmitters and more sensitive receivers, it is possible to achieve depths up to 1000 m.

4.2 *Complementary Data*—Geologic and water table data obtained from borehole logs, geologic maps, data from outcrops or other geological or surface geophysical methods (Guide D6429) and borehole geophysical methods (Guide D5753) are always helpful in interpreting subsurface conditions from TDEM/TEM survey data.

5. Significance and Use

5.1 *Concepts:*

5.1.1 All TDEM/TEM instruments are based on the concept that a time-varying magnetic field generated by a change in the current flowing in a large loop on the ground will cause current to flow in the earth below it (Fig. 3). In the typical TDEM/TEM system, these earth-induced currents are generated by abruptly terminating a steady current flowing in the transmitter loop (**2**). The currents induced in the earth material move downward and outward with time and, in a horizontally layered earth, the