ASCE STANDARD

ANSI/ASCE/
EWRI
44–13

Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects

This document uses both the
International Systems of Units (SI)
and customary units

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STANDARDS

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The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures
SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 listed with ASCE 3-91
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ASCE/EWRI 12-13 Standard Guidelines for the Design of Urban Subsurface Drainage
ASCE/EWRI 13-13 Standard Guidelines for the Installation of Urban Subsurface Drainage
ASCE/EWRI 14-13 Standard Guidelines for the Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-10 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ANSI/ASCE/T&DI 21-13 Automated People Mover Standards
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
ASCE/SEI 24-05 Flood Resistant Design and Construction
ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-09 Comprehensive Transboundary International Water Quality Management Agreement
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures during Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-11 Design of Steel Transmission Pole Structures
ASCE/SEI 49-12 Wind Tunnel Testing for Buildings and Other Structures
ASCE/EWRI 50-08 Standard Guideline for Fitting Saturated Hydraulic Conductivity Using Probability Density Functions
ASCE/EWRI 51-08 Standard Guideline for Calculating the Effective Saturated Hydraulic Conductivity
ASCE/SEI 52-10 Design of Fiberglass-Reinforced Plastic (FRP) Stacks
ASCE/G-I 53-10 Compaction Grouting Consensus Guide
ASCE/EWRI 54-10 Standard Guideline for Geostatistical Estimation and Block-Averaging of Homogeneous and Isotropic Saturated Hydraulic Conductivity
ASCE/SEI 55-10 Tensile Membrane Structures
ANSI/ASCE/EWRI 56-10 Guidelines for the Physical Security of Water Utilities
ANSI/ASCE/EWRI 57-10 Guidelines for the Physical Security of Wastewater/Stormwater Utilities
ASCE/T&DI/ICPI 58-10 Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways
ASCE/SEI 59-11 Blast Protection of Buildings
ASCE/EWRI 60-12 Guidelines for Development of Effective Water Sharing Agreement

FOREWORD

The Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee. The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are updated or reaffirmed by the same process every five years if at all possible. Requests for formal interpretations shall be processed in accordance with Section 7 of ASCE Rules for Standards Committees, which are available at www.asce.org. Errata, addenda, supplements, and interpretations, if any, for this standard can also be found at www.asce.org.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained therein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. Users are advised that the determination of patent rights or risk of infringement is entirely their own responsibility.

This standard, ASCE/EWRI 44-13, is a combination of ASCE/EWRI 44-05 and its supplement. The supplement covered substantive content and some editorial changes to Sections 1.2.1 through 1.2.5, Section 5.0, and Section 7.0, alone; the content in the remaining ASCE/EWRI 44-05 sections was unchanged. The supplement was prepared and developed through the ASCE consensus standards process, the remainder was undertaken by the AWM SC, then the final consensus for the Revision of ASCE/EWRI 44 was conducted before trying to obtain acceptance by ANSI. ASCE/EWRI 44-13 has been prepared in accordance with the ASCE Standards Writing Manual, August 20, 2010, revision with recognized engineering principles and should not be used without the user's competent knowledge of the underlying principles for a given application.

The American Society of Civil Engineers (ASCE) recognizes the work of the Atmospheric Water Management Standards Committee of the Environmental and Water Resources Institute (EWRI). The primary authors of this standard were the EWRI Atmospheric Water Management Standards Committee's Fog Dispersal Ad Hoc Subcommittee members: Thomas P. DeFelice (chair), Conrad G. Keyes, Jr., Darin Langerud, and Maurice Roos. We also acknowledge the many who contributed their comments, reviews, illustrations, and photographs.

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CHAPTER 1.0

INTRODUCTION

Fogs can pose a significant threat to public safety and quality of life in the air, on land, and at sea. For example, the luxury liner *Andrea Doria* collided with the *Stockholm* in fog off New York and sank on its 1956 maiden voyage. Fifty-one people died and millions of dollars in property were lost (Silverman and Weinstein 1974). An airliner (Flight VD8387) overran the runway in heavy fog after landing in Yichun, in northeastern China, killing 43 passengers on August 24, 2010. Extended periods of fog can have large economic impacts on the aviation, tourism, transportation, and mining industries (ASCE/EWRI 2005). For example, in the early 1970s one fog at one U.S. airport caused an estimated $100,000 loss of revenue due to aircraft diversions, delays, and cancellations (Silverman and Weinstein 1974). The total annual weather impact on U.S. aviation is an estimated $3 billion for accident damage and injuries, delays, and unexpected operating costs, and weather is a primary contributing factor in 23% of all aviation accidents (Kulsea 2002).

Although extended foggy periods can have negative impacts on agriculture and the mental health of the general public, there are some situations in which fog is beneficial, such as where fog water is collected for drinking water in arid regions (e.g., Schemenauer 1998), and where fog supplies some of the necessary moisture to vegetation. For example, fog supplies needed moisture to the northern California redwood trees during the summer dry season (e.g., Schemenauer 1998). Another example is the notorious winter fog in the San Joaquin Valley of California, which provides an important portion of the winter dormancy requirements of many deciduous orchard crops in the region. The San Joaquin valley fogs are also known as "tule" fogs and are in the category of "warm fogs" that are not normally supercooled, as their temperatures are often just above freezing (ASCE/EWRI 2005).

The harmful effects on transportation alone have been sufficient justification for attempts to modify or disperse fogs. Silverman and Weinstein (1974) note that fog was the subject of the first scientifically designed weather modification effort of any kind. This may partially explain why supercooled fog dispersal is perhaps the only weather-modification technology that does not require long experimentation and careful measurement to detect results, because results are both visible and nearly instantaneous. The most frequently cited goal of any supercooled fog dispersal project is to increase visibility. An increase in the local temperature can be a by-product of the clearing activities. Fog dispersal operations reduce the threat to public safety by increasing the visibility over highways and airport runways. Dispersing fog to increase visibility, especially at airports, has tremendous economic value—particularly at the local level—as transportation returns to normal levels. Additional sunshine resulting from fog dispersal operations can often improve the quality of life for specific populations. Fog clearing in open-pit mines can allow the safe resumption of mining operations that were suspended due to decreased visibility (ASCE/EWRI 2005).

Ice fogs are a special case and are slower to dissipate than supercooled fogs because they are composed mostly of tiny ice crystals and they generally form at air temperatures below about 243 °K (−30 °C) (e.g., Huffman and Ohtake 1971). Ice fog dispersal is fundamentally different from the dispersal of supercooled fogs and may be more appropriately labeled *ice fog suppression*. Ice crystals predominate and form by *heterogeneous nucleation* and, in some instances, by *homogeneous nucleation*. Ice fogs are primarily caused by unnatural sources of water vapor, which may include automobile and aircraft exhaust, exhaust from utility plants, and open water, such as cooling ponds (ASCE/EWRI 2005). Benson (1969) indicated that decreasing the ambient temperature of these moisture sources did improve visibility. Most attempts to disperse ice fogs have included electric fields, dehydrators of various types (e.g., gas, furnace, automobile), air movement by helicopters, polyethylene rafts, plastic films (e.g., polyethylene), injection wells, cooling towers, and chemical films (e.g., hexadeconal, ethylene glycol monobutyl ether). Presently, the standard technique used to suppress ice fog caused by exposed water sources employs a thin ethylene glycol monobutyl ether film. This film is harmless to marine life (it is biodegradable) and lasts much longer than other films, but it is less effective in suppressing ice fog than hexadeconal film (ASCE/EWRI 2005). McFadden (1976) and McFadden and Collins (1978) provide details of these techniques. Ice fog suppression techniques will not be discussed in this document. The focus of this standard is on the dispersal of supercooled fog.

1.1 HISTORICAL REVIEW OF SUPERCOOLED FOG DISPERSAL OPERATIONS

Supercooled fog is colloidally stable but is otherwise in a thermodynamically metastable state (e.g., Silverman and Weinstein 1974). Thus, supercooled fog can be dissipated by growth and sedimentation of ice crystals. Seeding supercooled fog with ice-forming particles (*nuclei*) may yield visibility improvements of at least 1.6 km (1 mi) within 15 min following seeding (Fig. 1-1). The results are so repeatable that randomized statistical verification is generally considered unnecessary. As a result, supercooled fog dispersal has been operational since 1950 in the United States and since 1952 in Russia. The most frequent locations of these operations are at airports. Suitable seeding techniques are primarily dependent upon wind, temperature, and the supercooled liquid water amount. Some involve the introduction of artificial ice nuclei into the air from either ground-based or airborne delivery systems. Other techniques employ liquid carbon dioxide, nitrogen, or propane to disperse fogs. Liquid