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U.S. Installation, Operation, and Performance Standards for Microturbine Generator Sets

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August 2000

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
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BATTELLE
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Executive Summary

As the nature of energy and electricity demand changes in the post-internet economy, demand for a variety of distributed energy resources (DER) grows -- natural-gas fired microturbines are just one of a suite of new power generation products entering (or soon to be) the U.S. marketplace. Developing an environmentally benign, efficient and cost-effective technology is paramount for all DER developers. But without the manufacturing, performance, installation and operation codes & standards necessary to support that technology, deployment--and ultimately financial success--may be delayed for years.

Microturbines are typically single shaft machines (one company is developing a twin-shaft) with the compressor and turbine mounted on the same shaft as the electrical generator. It therefore consists of only one rotating part, eliminating the gearbox and associated moving parts. This direct-drive, high-speed design has enabled manufacturers to create a more reliable compact power plant than traditional engine generator sets.

Codes and standards that regulate the safe performance of microturbine generators in or near buildings outside traditional utility jurisdiction will fall into one of three realms, and have been separated into chapters within this report.

Manufacturing Standards involve the materials, design and construction of a single unit, commonly referred to in the C&S industry as "the box." Microturbines do not currently have a manufacturing or performance standard by which each unit can be evaluated. Underwriter's Laboratories has listed one company's product under UL 2200, "Stationary Engine Generator Assemblies." The standard is under review for modifications to include microturbines by reference.

Installation and Operation Standards address electrical- and fire-safety, and life-safety requirements such as emergency backup systems for life-support operations or mission-critical systems. UL 2200 is most relevant here, as is EGSA 101, NFPA 37, 101 or 110, IEEE 519 (harmonic distortion) or ASME B133.8 (noise emissions).

Interactions Between the MT Unit and Other Building Systems include fire protection, egress, ventilation, electrical shock protection, and fuel supply. The building code official will want to see sufficient space around, access to, and protection of the MT unit to ensure public safety under all conditions.

Historically, wide-scale power generation technologies have been owned and operated by regulated utilities and have not been subject to local code requirements. However, in 2000, the International Building Code declared that utility-operated facilities not owned by--and dedicated to--the utility will fall under local code jurisdiction. Currently, no technology-specific code structure exists for the installation and base load operation of microturbines by private nonutility parties in commercial or residential buildings.

In such cases when a technology is not specifically referenced in the applicable code documents, code officials may disallow the installation and operation of that unit. Building officials may require specific tests to demonstrate "alternative compliance"; performing the necessary site-specific studies--possibly requiring modifications to the installation--can increase the installed cost of a unit beyond any reasonable expectation for return on investment. Further, with 44,000 state and local code jurisdictions in the United States, the absence of any reference in the national code bodies may kill altogether the early prospects for the mass deployment of a new energy technology such as microturbines.

This report reviews the codes and standards applicable to the safe installation and operation of microturbines in commercial and residential buildings. It provides an overview of potential regulatory roadblocks, as well as recommendations for further action that may be undertaken by the U.S. microturbine community.

This report does not attempt to provide a technical review of any manufacturer's product, nor does it involve any technology-specific analysis (i.e., comparing the output current grounding design of one manufacturer, against UL 2200 requirements for Stationary Engine Generator Assemblies).

This study did not find that additional standards are required for building code officials to accept microturbine installations when external to a commercial or industrial facility. However, a general lack of education among code officials on the differences between DER installations and traditional backup generators, is in fact hampering the deployment of microturbines. A general education program for building code officials is in order. The report closes with the recommendation to pursue a performance standard specifically for microturbines, and for those applications most relevant to the emerging DG market--combined heat & power, premium power quality.

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1.0 Introduction

Codes and standards that regulate the safe performance of microturbine generators in or near buildings outside traditional utility jurisdiction will fall into one of three realms:

- manufacturing specifications and design requirements of the unit or system (i.e., “the box”)
- installation and operation
- interactions between the microturbine unit and other building systems, structures, or life-safety issues.

Historically, wide-scale power-generation technologies have been owned and operated by regulated utilities and have not been subject to local code requirements. However, in 2000, the International Building Code declared that utility-operated facilities not owned by--and dedicated to--the utility will fall under local code jurisdiction. Currently, no technology-specific code structure exists for the installation and baseload operation of microturbines by private nonutility parties in commercial or residential buildings.

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1.1 Microturbine - Definitions

Microturbines are typically single-shaft machines (one company is developing a twin-shaft) with the compressor and turbine mounted on the same shaft as the electrical generator. It therefore consists of only one rotating part, eliminating the gearbox and associated moving parts. This direct drive high-speed design has enabled manufacturers to create a more reliable compact power plant than traditional engine generator sets.

The fuel of choice is natural gas delivered at pressures exceeding 55 psi (this requirement may go as high as 90 psi), although low-pressure gas can be boosted with centrifugal or scroll-type compressors. Systems can operate on propane as well, which requires on-site fuel storage.

Virtually all MTs are installed with recuperators to achieve 28-30% electrical efficiency. Unrecuperated MTs generally run at 14-17% efficiency (LHV). The recuperator is a heat exchanger, transferring heat from the exhaust gas to the discharge air. Before it enters the combustor, the exhaust gas is reduced to near compressor discharge temperature and the compressor discharge air is heated to near turbine exhaust gas temperature. The heat added to the air reduces the amount of fuel required to raise the temperature to that required by the turbine.

The electrical output is a high-frequency AC (1500-4000 Hz, 3-phase). The voltage is rectified and inverted to a normal 3-phase 50 or 60 Hz. In most systems, the power inverter and the alternator are used as the turbine starting system. In some cases two 12-volt batteries provide system power; those without "black start" capability (e.g., capable of starting independently) require AC power from the grid for their initial starting operation.

1.2 Methodology

This report was prepared by analyzing manufacturer's specifications against the most common industry sources for design, manufacturing, performance, installation and operation standards for electrical equipment installed in the United States. The following agencies provided primary or secondary information in this report:

American National Standards Institute (ANSI)
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
American Society of Mechanical Engineers (ASME)
American Society for Testing and Materials (ASTM)
Electrical Generating Systems Association (EGSA)
Institute of Electrical and Electronics Engineers, Inc. (IEEE)
National Electrical Manufacturers' Association (NEMA)
National Evaluation Service (NES)
National Fire Protection Association (NFPA)
Underwriters Laboratories (UL)

2.0 Current Codes and Standards

Building codes and manufacturing and installation standards were not developed with the intent of regulating the generation and distribution of electricity (considered to be a function of regulated utilities). Nor were the codes developed to regulate the generation and possible distribution of electricity by others. Insurance companies, lenders, building owners, tenants, occupants, and the general public expect buildings to be safe places. The code official is charged with protecting health and life-safety in buildings. He or she also is charged with enforcing codes as they currently exist. Because existing codes and standards were not written with specific requirements for generation and distribution of electricity by microturbine products, trying to apply them to technologies they were not intended to address places the enforcing agency (most likely a municipality) at risk for liability in a life- or property-threatening event.

Where there is no clear direction from codes and standards, there is potential for differing interpretations. These differing interpretations lead to differing installation requirements that can significantly impact both costs and length of time between purchase and operation. In evaluating a proposed installation design, particularly when submitted under the code provision "alternative methods and materials," a code official may require that the design undergo extensive engineering analysis and specialized testing before granting approval.

For the various codes and standards to formally mention DG products, the lag-time is approximately three years. Most national model codes operate under a three-year revised publication cycle. To avoid future code-related conflicts, changes proposed for a specific code must be fully integrated and coordinated with other codes. Where possible, code change proposals should address the full range of DG products. Uniform requirements for grid interconnection for all DG products would be preferable to requirements that vary by product. DG manufacturers, utilities, and others should work together on codes and standards issues to develop code change proposals for uniform requirements that will be adopted by the national model code agencies. The alternative could be a maze of requirements that serves as another barrier for design professionals, contractors, utilities, and code officials. Collaboration and cooperation can produce uniform code requirements that expedite the installation of DG products.

This chapter provides an overview of the U.S. standards and codes most likely to be relevant to microturbine technologies. Voluntary consensus standards are summarized in Section 2.1; model codes are discussed in Section 2.2.

2.1 Voluntary Consensus Standards

Voluntary consensus standards are documents that can be used or referenced to ensure uniformity in the testing, rating, evaluation, or design of products, materials, and other items. The term consensus is used to describe general agreement but not necessarily unanimity on a particular issue. Standards generally are referenced or transcribed within model codes. Standards also usually are focused on a specific aspect of the subject of interest.

2.1.1 Types of Standards

Product testing standards or test methods provide for the uniform testing and evaluation of a product or material. One example is a test to determine the combustion characteristics of various building materials (rate of flame spread, smoke emission profile, etc). Although other documents establish the maximum acceptable values for these effects, a uniform test is necessary to determine these numbers irrespective of material, so different materials/products can be compared fairly.

Rating standards address the performance of a specific product or material. An example of a rating standard is one for air-source heat pumps developed by the Air Conditioning and Refrigeration Institute (ARI). Such a standard allows all such equipment to be tested and rated so the output at various input and ambient conditions can be measured and results equitably compared from manufacturer to manufacturer. Other examples in this category include tensile strength and/or flexibility of a stated material (concrete).

Minimum acceptable **design or construction standards** typically do not involve testing or rating a specific product, but rather the attributes required in a specific building design. For this reason the systems interacting within–and reacting to--that design may prove to be difficult to quantify. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.(ASHRAE) Standard 90.1 consumed a decade of analysis, debate and open meetings before establishing criteria to represent an energy-efficient commercial building.

Voluntary consensus or industry standards are neither legislation nor regulations. However, these standards might be adopted into law by federal, state, or local agencies. Until adopted, they are as the name implies—voluntary. As new technologies, products, or processes are developed, new standards typically rise to cover testing, rating, and design.

Circular A119 of the U.S. Office of Management and Budget requires federal government agencies to use voluntary standards for regulatory and procurement purposes, when appropriate.

2.1.2 Standards Developers

The following paragraphs provide brief descriptions of organizations most involved in the development of standards related to the power generation industry. These organizations do not write the standards but provide the protocols and process support for standards development. While staff members provide the necessary support functions, the actual development and maintenance of a given standard and technical interaction with those who comment on that standard are performed by volunteers who represent a broad range of interests.

Although the American National Standards Institute (ANSI) coordinates standards initiatives within the United States, there are those who do not use ANSI processes. In addition, there are standards initiatives in many other countries as well as at the international level. These may be known to ANSI, especially where the U.S. has some involvement in the international level activities. If information on standards development is desired, ANSI should be contacted first, followed by a contact to the likely standards generating organization, trade association representing the technology or issue in question, and manufacturers or others involved with the subject area. The National Institute of Standards and Technology (NIST) is another source of information on standards.

American National Standards Institute (ANSI)

ANSI is the dominant developer of consensus standards in the United States today, with over 13,000 consensus-based national standards in existence. ANSI is the sole U.S. representative of the two major non-treaty international standards organizations, the International Organization for Standardization (ISO), and, via the U.S. National Committee (USNC), the International Electrotechnical Commission (IEC). ANSI is also one of five permanent members to the governing ISO Council, and one of four permanent members of ISO's Technical Management Board. Through its ISO representation, ANSI has the authority to vest Technical Committees (TCs) in concert with international standards-making bodies.

U.S. standards are frequently presented for consideration (through ANSI) to the ISO or IEC where they are adopted in whole or in part as international standards.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)

The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.(ASHRAE) is a 50,000-member international organization with chapters throughout the world. The society is organized for the sole purpose of advancing the arts and sciences of heating, ventilation, air conditioning and refrigeration for the public's benefit through research, standards writing, continuing education and publications.

Through its membership, ASHRAE writes standards that set uniform methods of testing and rating equipment and establish accepted practices for the heating, ventilation, air-conditioning, and refrigeration (HVAC&R) industry worldwide, such as the design of energy-efficient buildings. The Society's research program, currently more than 100 research projects worth nearly $8 million, investigates issues such as identifying environmentally benign refrigerants. ASHRAE organizes broad-based technical programs for presentation at its semiannual meetings and co-sponsors the International Air-Conditioning, Heating, Refrigerating Exposition, the largest HVAC&R trade show in North America.

ASHRAE writes standards and guidelines in its fields of expertise to guide industry in the delivery of goods and services to the public. ASHRAE standards and guidelines include uniform methods of testing for rating purposes, describe recommended practices in designing and installing equipment, and provide other information to guide the industry. ASHRAE has some 87 active standards and guideline project committees, addressing such broad areas as indoor air quality, thermal comfort, energy conservation in buildings, reducing refrigerant emissions, and the designation and safety classification of refrigerants.

Of most importance to the microturbine development community, ASHRAE Technical Committee 9.5 is currently studying the possibility of developing a standard for cogeneration systems. It is vital that the microturbine community be involved in this effort.

American Society of Mechanical Engineers (ASME)

The American Society of Mechanical Engineers (ASME International) has been involved in the development of codes, standards, and conformity assessment programs since 1884. The organization maintains and distributes 600 codes and standards used around the world for the design, manufacturing, and installation of mechanical devices.

ASME B133 is the ASTM-referenced standard for gas turbine procurement; included within this family of standards are subcommittees on fuels, performance, controls and auxiliary equipment, maintenance and reliability, and sound emissions. These standards were developed in the 1980s and have not been updated to include microturbines.

American Society for Testing and Materials (ASTM)

The American Society for Testing and Materials (ASTM) is a not-for-profit organization that provides a forum for standards development for materials, products, systems, and services. From the work of 132 standards-writing committees, the ASTM publishes standard test methods, specifications, practices, guides, classifications, and terminology. The ASTM's standards development activities encompass metals, paints, plastics, textiles, petroleum, construction, energy, the environment, consumer products, medical services and devices, computerized systems, electronics, and many other areas. ASTM Headquarters has no technical research or testing facilities; such work is done voluntarily by 35,000 ASTM members throughout the world.

More than 10,000 ASTM standards are published each year in the 72 volumes of the Annual Book of ASTM Standards. These standards and related information are sold throughout the world.

Electrical Generating Systems Association (EGSA)

The Electrical Generating Systems Association (EGSA) is the association for on-site power generation. Its members include manufacturers, dealer/distributors, manufacturers' representatives, consulting engineers, and others interested in the on-site power-generating industry and the components of electrical power-generating systems. The association develops educational materials, conducts seminars, publishes the bimonthly magazine "Powerline," sponsors technical meetings, and develops national standards involving the use of on-site power. In addition to these inter-industry standards, the EGSA works to develop performance standards for equipment and components specific to its industry

Institute of Electrical and Electronics Engineers, Inc. (IEEE)

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) is a not-for-profit association and has more than 330,000 individual members in 150 countries. Through its technical publishing, conferences and consensus-based standards activities, the IEEE produces 30% of the world's published literature in electrical engineering, computers, and control technology, holds annually more than 300 major conferences, and has more than 800 active standards with 700 under development.

National Electrical Manufacturers' Association (NEMA)

The National Electrical Manufacturer's Association develops standards for electrical component or original equipment manufacturers. The organization publishes 200+ standards for

- building equipment
- diagnostic imaging and therapy systems
- electronics
- industrial automation
- industrial equipment
- insulating materials
- lighting equipment
- power equipment
- wire and cable products

NEMA standards are commonly cited in DOD regulations, the National Electrical Code, UL standards, and DOE standards for electric motors. NEMA is also a founding member of CANENA (Council for the Harmonization of Electrotechnical Standards of North America), a tri-national organization devoted to harmonizing NAFTA-member standards for electrical equipment.

National Fire Protection Association (NFPA)

The National Fire Protection Association (NFPA) is an international, nonprofit, membership organization founded in 1896 to "protect people, their property and the environment from destructive fire."

The NFPA publishes the National Electrical Code, the Life Safety Code, the Fire Prevention Code, the National Fuel Gas Code, and the National Fire Alarm Code. The organization operates in 100 countries with 65,000 volunteers and staff.

NFPA codes most commonly referenced by local code officials include

- NFPA 1, Fire Prevention Code
- NFPA 13, Standard for the Installation of Sprinkler Systems
- NFPA 54, National Fuel Gas Code

- NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases
- NFPA 70, National Electrical Code
- NFPA 72, National Fire Alarm Code
- NFPA 101, Life Safety Code

Underwriters Laboratories (UL)

Underwriters Laboratories Inc. (UL) is an independent, not-for-profit product safety testing and certification organization. Founded in 1894, UL has five testing laboratories in the United States and subsidiaries in Mexico, Denmark, England, Italy, India, Singapore, Taiwan, Hong Kong and Japan. The organization also has numerous international, affiliate, and representative offices, as well as field representatives located throughout the world. Most significant for the microturbine community, UL 2200 is the product standard by which microturbines are currently being rated.

UL-Canada Mark

Through the provisions of agreements between UL and Canadian certification organizations, UL clients can receive UL and Canadian certifications with one submittal. These agreements provide for the reciprocal acceptance of test results and cover a wide range of products.

UL has been granted Certification Organization (CO) and Testing Organization (TO) accreditations for Canada by the Standards Council of Canada (SCC). UL's CO accreditation encompasses all of its facilities that handle both certification and testing, and all of its product categories and programs. By virtue of this accreditation, UL can evaluate products intended for the Canadian marketplace to Canadian National Standards and Codes, and authorize clients to label those products with the UL Mark for Canada.

2.1.3 Consensus Standard Development Process

A new technology, government directive, or other phenomenon may create the need to test, rate, or otherwise evaluate something that has not been addressed previously. An example is the development of ASHRAE Standard 90 dealing with building energy efficiency in 1975. This was a direct response to the 'Energy Crisis' and the need expressed by some states for criteria on energy conservation that could be incorporated into their building codes.

Once the need is identified (and a draft standard developed by some interested entity as a "strawman"), the individual or organization with the greatest desire for standardization will seek out a standards developer and request the developer to initiate standards development. In the case of ASHRAE, the organization's Standards Committee makes the decision to establish new 'Standards Project Committees.' Within the NFPA, the Standards Council makes the decisions on new projects.

The standards developer, typically with help from the standards instigator, will draft a title, purpose, and scope (TP&S)for the standard. These establish the framework for the standards project. This document, along with an expression of the need for the standard, is then considered by the committee that has such approval authority (Standards Committee, Standards Council, and so on). These committees may also consider conflicts with other existing standards and the scope of the project as it relates to the goals and objectives of their organization.

2.2 Model Codes

Model codes are just as the name implies—models of a code that anyone (typically federal, state, or local agencies) can adopt to address design, construction, and operation of buildings and facilities. Without a model code, each adopting entity would have to develop its own unique criteria—a costly, time-consuming, and easily outdated process. Model codes are written in enforceable language that meets the needs of the enforcement community. Model codes are written in a prescriptive manner so that the requirements are easily understood. Model codes usually present detailed prescriptive criteria and then allow alternative materials, methods or equipment based on performance equivalency.

They contain minimum requirements that are needed to protect the health, life-safety, and welfare of the public. Issues such as carpet quality would not be addressed within a model code, although the fire characteristics of the carpet would be addressed.

Model codes are not legislation or regulations, nor are they standards as described in Section 2.1., but when formally adopted, they do become enforceable law. Model codes rely on standards developed by others and refer to them as needed. A model code provides the regulatory framework under which a standard can be referenced.

Model codes offer an equal opportunity to all to participate in the development and revision process. Anyone can submit a code change; publication of code changes is available to all who request copies and open hearings are held, in which the merits of each proposed change are debated. The code officials vote on what they consider acceptable changes, based on oral and written testimony, and changes are finalized every year. This contrasts with the standards development process, in which it is possible to intervene in the process of development and publication through numerous comment and appeal processes.

Within each of the model codes, numerous subject areas are covered. And revisions to one subject area may impact (or be affected by) other areas. For example, studies have shown that energy could be conserved in some climatic locations if cathedral ceilings did not have to be ventilated. The building code mandates such ventilation and overrides the energy code. The use of photovoltaic shingles may be impacted by provisions in the building code for roof coverings. The mechanical code contains provisions for the safe installation of ground source heat pumps, which could adversely affect the deployment of that equipment. The fuel gas code has, in some instances, precluded the installation of high-efficiency gas heating equipment because it did not meet the venting requirements contained in the code.

The national model building codes generally incorporate by reference other model codes and standards as establishing the requirements for specific equipment installations or systems such as electrical, fuel gas, mechanical plumbing, and fire protection. Provisions of the building codes apply to the construction, alteration, moving, demolition, repair, maintenance, and use of any building or structure. State and local amendments may expand the scope of the national models to include such specific issues as emissions, air quality, noise levels, and other siting concerns.

Model codes are important because they form the basis for the vast majority of federal, state, and local building construction regulations in the U.S. New York state and city, Wisconsin, Chicago, and Dade and Broward Counties in Florida are a few government entities that continue to write their own codes. There are over 44,000 jurisdictions (county, city) in the U.S. that could adopt and enforce codes. Even at the state level (about 25 states have statewide codes) writing and maintaining a building code is a time-consuming process. The model codes provide efficiency and uniformity for these potential "customers.".

A code mandate to install specific devices (i.e., smoke detectors) can have a profound impact on product sales for a particular industry. Conversely, excessive installation and test criteria within a code, for certain products or equipment, can have the opposite negative impact on an industry.

2.2.1 Types of Model Codes

Building construction regulations provide the minimum requirements that a building and its systems, materials, and equipment must meet, and may vary by county, state or federal jurisdiction. The charter of building codes is to "safeguard life or limb, health (occasionally property), and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy location and maintenance of all buildings and structures and certain equipment specifically regulated" [Uniform Building Code (ICBO), International Conference of Building Officials (1997)].

2.2.2 Model Building Code Developers

Historically, model building codes were developed by three regional organizations outlined below: ICBO, BOCA, and SBCCI. The three regional model codes often had overlapping and contradictory building requirements, increasing the difficulties developers faced in managing production and equipment acquisition costs. In the 1994 the three model code groups agreed to work cooperatively within a single code organization to develop national building guidelines (see 'ICC' below).

As previously noted, the NFPA also develops documents that employ "code language" and as such could be classified as "model codes". Because these documents are developed by a standards organization, they are not thought of as model codes even though they are formatted, adopted, and used in much the same way as model codes. NFPA 70 and 54 (National Electric Code and National Fuel Gas code) are two examples.

International Building Code 1997 - International Code Council (ICC)

In 1994 the model code groups formed the ICC and set out to develop one set of model codes. This family of international codes (I-codes) includes but is not limited to Energy Conservation, Fuel Gas, Mechanical, One- and Two-Family Dwelling, Plumbing, Building, Fire, and Residential. Currently the ICC is on schedule to publish in final form all ICC codes by 2000. However, adoption of the ICC codes by jurisdictions will be a slow process, because many jurisdictions must adhere to specific schedules, or must continue to use existing codes until there is justification for change.

The regional model code groups will continue to operate. While cooperating within the ICC, they will continue to 'compete' in serving the building and code communities as they have in the past (through education, plan review, and other member services).

Uniform Building Code 1997 - International Conference of Building Officials (ICBO)

The Uniform Building Code has been the dominant choice for adoption and enforcement by mid-western and western states including Indiana, Iowa, Minnesota, North Dakota, South Dakota, Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Idaho, Washington, Oregon, California, and Alaska. Provisions of the code shall apply to the construction, alteration, moving, demolition, repair, maintenance, and use of any building or structure. This building code references other codes for specific systems such as electrical, HVAC, plumbing, and fire protection. It does not specifically reference microturbines, nor place special restrictions on structures that might house or support microturbines.

National Building Code 1996 - Building Officials and Code Administrators International (BOCA)

With the exception of New York, the states of the northeast extending south to include Virginia, West Virginia, and Kentucky, have traditionally been considered the territory of the National Building Code.

Standard Building Code 1997 - Southern Building Code Congress International (SBCCI)

The Standard Building Code has been the predominant code for southeastern states including Louisiana, Arkansas Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi.

2.3 State Authority

Model codes are developed at the national level, but they have no legal authority until individual states or local governments adopt them. Some states have a mix of national model codes; some states have none because there is no authority to adopt a code on a statewide basis. In the latter situations, local jurisdictions may elect to adopt the code of their choice and make local amendments. Some states have passed legislation that establishes the code that jurisdictions must adopt if they elect to adopt a code. This promotes uniformity and consistency across jurisdictional lines within the state and facilitates compliance and inspection.

Developers of new power generation technologies, whose products may be installed in non-traditional IPP locations (residential and small commercial facilities), will need to develop an industry standard for their product, lobby for its adoption/reference in the national model codes, and then work with state agencies to have the model code adopted and enforced. This is a long-term effort for which the DOE already has state outreach programs in place to provide assistance.

3.0 Manufacturing Standards: "The Box"

As noted in Chapter 2, voluntary consensus standards are developed by a variety of organizationsjeanThese standards then may be referenced by model codes and adopted by state or local government organizationsjeanIEEE, ASME, ASTM, and NEMA are particularly active developers of consensus standardsjeanAlthough no manufacturing standards currently exist for microturbine generator sets as a complete, separate product, several standards from these organizations are relevant to the components of microturbines.

Underwriters Laboratories has worked with microturbine developers to list their product as an alternative to UL 2200, Engine-Driven Generator SetsjeanBeyond this, options currently available to the microturbine community include:

- request for revisions or additions to UL 2200, providing design specifications for microturbines
- development of a manufacturing or design standard specifically for microturbines by one of the standards-developing organizations mentioned earlier
- third-party testing and certification (see chapter 6), which may be acceptable to many code authorities.

The microturbine industry is not the first among DG developers to address code issues for technologically advanced onsite generation. The U.S. fuel cell industry has successfully developed a consensus standard, ANSI Z21.83, Fuel Cell Power Plants, which evaluates the construction safety and performance safety of a fuel cell power plant using natural gas or liquified petroleum (LP) gasjeanIn addition, fuel cell installations now are referenced in the National Fire Code.

PTC 50, Fuel Cell Power Systems Performance, contains methods and procedures for conducting and reporting fuel cell system testing, instrumentation to be used, testing techniques, and methods for calculating and reporting results.

3.1 ASME/ANSI B133, Gas Turbine Procurement

This suite of standards deal with procurement standards for gas turbines in industrial marine and stationary power applications. They are not currently considered applicable to microturbines.

3.2 UL 2200, Stationary Engine Generator Assemblies

This is the standard currently used by third-party testing organizations to list microturbines, although it is not an ASME- or IEEE-equivalent manufacturing or performance standard. It deals almost exclusively with electrical safety issuesjeanCurrently microturbines are not referenced by name; however, UL is reviewing their work performed for manufacturers to identify which sections will require revision to make allowance for microturbine systems.

As currently written, UL 2200 covers stationary engine generator assemblies rated 600 volts or less installed and operated in non-hazardous locations in accordance with NFPA-37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines; NFPA 99, Standard for Health Care Facilities; and NFPA 110, Standard for Emergency and Standby Power Systems.

Because UL 2200 is essentially a safety standard, it contains practical requirements for the design, construction and installation of any engine- or turbine-generator assemblyjeanNone of the basic performance data given for the microturbine designs being considered in this review is in direct conflict or in direct violation of this standard’s requirementsjeanHowever, sections that address the prime mover (historically an IC engine) will require a comprehensive review for microturbine combustors, inlet temperatures and gas pressure, electrical output, etc. Please see chapter 4 for additional information on UL 2200 as a safety standard.

4.0 Installation and Operation Standards

Underwriters Laboratories (UL), the Electrical Generating Systems Association (EGSA), and the National Fire Protection Association (NFPA) have developed standards most relevant to microturbine installations. Those three standards are summarized in this chapter.

4.1 UL 2200, Stationary Engine Generator Assemblies

This standard deals almost exclusively with safety issues in relation to electrified equipment. It does not cover any mechanical performance standards of the prime mover and ancillary equipment. Currently microturbines are not referenced by name in the standard, although this is the central document by which third-party testing organizations are listing microturbine products as safe for operation.

The requirements spelled out in this standard cover stationary engine generator assemblies rated 600 volts or less that are intended for installation and use in ordinary locations in accordance with the National Electrical Code, NFPA-70; the Standard for the installation and Use of Stationary Combustion Engines and Gas Turbines, NFPA-37; the Standard for Health Care Facilities, NFPA-99; and the Standard for Emergency and Standby Power Systems, NFPA-110.

These requirements do not cover 1) generators for use in hazardous (classified) locations; 2) uninterruptible power source (UPS) equipment; or 3) generators for marine use.

The contents of UL 2200 are in terms of the following sections:

Construction of the Unit—Consists of essential features for general protection, controls, accessible circuits, and other mechanical and electrical subassemblies. Section 34 at the end of this part deals with requirements for "Protection of Service Personnel." This part of the standard mandates, among other requirements, a minimum thickness of the cast metal enclosures and sheet metal enclosures of the generator assemblies; a minimum thickness for nonmetallic enclosures (UL 746C); flammability limits (UL 94); and minimum thickness and maximum area requirements for glass-covered openings.

Mechanical Systems—Construction—Deals mainly with fuel systems and exhaust systems.

Mechanical Systems—Performance—Deals with several testing requirements, including tests for harmonic distortion, voltage and frequency fluctuation, salt sprays, grounding impedance, overcurrent protection calibration, and impacts, among others.

Marking—details and instruction manual

Manufacturing and Production Tests—Production-Line Dielectric Voltage-Withstand Test

Outdoor-Use Units—Requirements for these units supplement and, in some cases, modify the general requirements given above.

Standards for Components—Lists the UL standards with which components of the generator sets must comply.

Because UL 2200 is essentially a safety standard, it contains requirements primarily focused on electrical output safety performance measures that are mandatory for the design, construction and installation of any engine- or turbine-generator assembly. None of the basic performance data given for the microturbine designs being considered in this review is in direct conflict or in direct violation of this standard's requirements.

4.2 EGSA 101P-1995, Performance Standard for Engine Driven Generator Sets

The requirements defined in 101P were compared with specifications of a manufacturer's turbo alternators, either available or planned, with nominal outputs in the 45-kW to 200-kW range, and also with specifications for a 30-kW device.

The primary conclusion is that 101P is currently incomplete as a performance standard. It contains a mixture of qualitative, quasi-quantitative, and fully quantitative requirements together with tutorial sections that express no requirements. While it might be considered a baseline from which to develop a performance standard, it lacks sufficient detail to be useful. Finally, as 101P relies extensively on other referenced standards, it should be asked whether or not it represents redundancy.

Subsection 8.2 provides the greatest concentration of quantitative performance requirements within this standard. Of note, however, is the lack of cross-referencing all the other standards listed in Section 2. This appears to be an incomplete standard for determining the adequacy of a microturbine installation and operation.

4.2.1 Applications Criteria

Modes of Operation—Somewhat advisory in declaring the operating modes of the generator set must be considered when the purchaser negotiates requirements with the equipment supplier.

Generator Set Rating Definitions—Subsections 3.2.1 through 3.2.4 define the terms Emergency Standby Rating; Limited Running Time Rating; Prime Power Rating; and Industrial Rating. The Prime Power Rating requires a minimum momentary overload capability of 10%.

Application Classes—Subsections 3.3.1 through 3.3.4 define four application classes and their associated, progressively less severe, qualitative requirements on frequency, voltage, and waveform.

Criteria of Use—Subsections 3.4.1 and 3.4.2 distinguish land use from marine use.

Classification of Operation—Subsections 3.5.1 and 3.5.2 distinguish the character of Single Unit Operation from Parallel Operation.

4.2.2 Prime Mover

Engine Configuration—Requires assurance from the manufacturer that the engine is fit for service. Requires engine conformance with EGSA 101S and ISO 3046.

Engine Types—States focus of the standard is predominantly diesel but applies generally to gas turbine, gasoline, or natural gas engines.

4.2.3 Generators (Alternators)

Design Standards—Requires generators be designed to meet appropriate sections of NEMA MG1 and IEC 34. Note: The latter was not listed in Section 2. This subsection refers to maximum temperature rise defined in NEMA MG 1 and torsional compatibility of generator set components.

Ratings—Equipment rating stated in kW or kVA at assumed minimum power factor of 0.8 lagging and at specified voltage and current.

4.2.4 Voltage Regulators (See EGSA STD 100R)

Application—Defines when VR is needed.

Voltage Sensing—May be single or 3-phase.

Voltage Adjustment— ±5% of nominal rated voltage

Voltage Regulation Accessories—Covers in 6.4.1 through 6.4.5 parallel operation, motor starting, under frequency protection, over voltage protection, and electromagnetic interference. Two of these are hard requirements (provision for reactive droop compensation and under frequency protection); the other three appear to be purely advisory.

4.2.5 Control and Monitoring Panel

Configuration—Refer to 101S.

Construction—Must conform with applicable NEMA and ANSI standards.

Instrumentation—Legibility recommendation for scales and metering accuracy requirements (±2% for ac electrical instruments and ±10% for engine instruments/indicators).

Current Rating—Current carrying capacity requirements for conductors and components (should be sufficient for service).

Identification of Components—General good human factors design requirements for component identification

Electrical Protection-Requirement for short-circuit protection and recommendations for other related practices, including some that belong in 7.5.

4.2.6 Complete Generator Set

Terms and Expressions—Defines quantities measured by representative voltage strip chart (8.1.1) and frequency strip chart (8.1.2). No requirements, just definitions.

Unit Starting and Load Acceptance—Contains three requirements: 1) emergency (must be started, on line and under load in 10 seconds or less); 2) standby (must be started, on line and under load in 1 minute or less); and 3) additional starting aids (use of aids; e.g., engine coolant and battery temperature control, glow plugs and/or oil heating) under severe conditions.

Rated Power—The generator set must be capable of producing its rated power at rated frequency, voltage, and electrical power factor, corrected to standard ambient conditions per SAE J1349.

Governor Performance for Application Classifications—Contains definitions and quantitative requirements relating to frequency regulation.

Voltage Regulation—Subsection 8.2.4.1 requires steady state VR no more than 2% between no load and full rated load (per EGSA 100R). It also defines requirements for random voltage variation and voltage sensitivity to temperature. Subsection 8.2.4.2 provides advice on the tailoring of self regulated alternator voltage.

Excitation Support System (Optional)—Defines 2.5 per unit exciter current requirement when applicable.

Unbalanced Loads—Recommends keeping unbalance to less than 20%; connecting no more than 1/3 of nominal kVA rating to any one phase of a 3-phase system and requirements for delta, delta-delta or open delta connections together with voltage unbalance limits.

Waveform and Telephone Influence Factor—Defines maximum allowable harmonic content and telephone influence factors for application classifications listed in Section 3.3.

Overspeed—The generator should tolerate 25% overspeed for 10 seconds without damage. Overspeed protection should activate at 20% over maximum rated synchronous speed.

Engine Cooling System—Defines cooling water temperature limit under specified conditions of antifreeze content, ambient temperature, elevation and radiator air-flow restriction.

Engine Air Cleaner—Defines type and performance requirements for engine air cleaners.

4.3 ASME B133.6, Gas Turbine Ratings and Performance

This standard was originally developed to provide a performance rating system for installation sites that do not have sufficient data on ambient conditions to use the manufacturer's ratings. Because it was last updated in 1994, it does not currently apply to the microturbine products commercially available today.

4.4 NFPA 37, Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines (1998)

NFPA 37 concerns the installation of engines for stationary power. NFPA 99 references NFPA 37 in the text and NFPA 110 references it in the appendix. Textual references make the standard mandatory. Appendix references are for information only. The International Mechanical Code (IMC) also references NFPA 37 for engines powering equipment and appliances.

Chapter 2 gives requirements for mounting, locating, and housing engines. Persons quoting generator sets requiring conformity with NFPA 37 should be aware of Par. 3-3.1(b) and (f). These often overlooked clauses requires lubricating oil over temperature shutdown (b) or indication (f) for engines over 100 horsepower.

Chapter 5 is the reference for liquid-fueled engine fuel tank and daytank installations. This chapter gives some details, such as a table for day tank steel thickness, but frequently references NFPA 30, Flammable and Combustible Liquids Code. Chapter 4 does the same thing for gas-fueled engines and references NFPA 54, National Fuel Gas Code and NFPA 58, Standard for Storage and Handling of Liquefied Petroleum Gases.

Chapter 6 covers exhaust piping and chimneys. It gives details for safe exhaust piping routing and installation. Examples are material of wrought iron or steel and drains for low points in the line. For chimneys, the standard references NFPA 211, Standard for Chimneys, Fireplaces, Vents and Solid Fuel Burning Appliances.

NFPA 37 has only seven pages of text but be especially aware of Chapter 10, Mandatory Referenced Publications. It lists some 13 additional standards that must be reviewed for each installation.

4.4.1 NFPA 37 Scope - Size Limits

The previous 7500-horsepower limitation in the scope of the standard has been removed. There is no minimal horsepower threshold for engines or gas turbines so microturbines would be subject to the requirements set forth in this standard.

This standard applies to fire safety for the installation and operation of stationary combustion engines and gas turbines. It also applies to portable engines that remain connected for use in the same location for a period of one week or more and that are used instead of or to supplement stationary engines. For engines used in essential electrical systems in health care facilities, also see NFPA 99, Standard for Health Care Facilities. For engines used in emergency power supplies, also see NFPA 110, Standard for Emergency and Standby Power Systems.

The term **combustion gas turbine** as used is inclusive of microturbines and, therefore, the standards requirements apply to microturbines. The standard does not address the electric generating component of the microturbine generator unit.

Chapter 3 of the standard addresses general requirements for engine locations (in, on, and outdoors near buildings), electrical installations in rooms containing engines (NFPA 70 by reference), engine wiring, and other general installation requirements (reference to applicable NFPA codes and standards), and to those portions of existing equipment and installations that are changed or modified establishes requirements for locating microturbine engines in, on, or near buildings.

Chapter 4 addresses gas piping and references NFPA 54 for systems at service pressures of 125 psig and less and NFPA 58 for LP-gas systems. It prescribes the minimal components of a gas train for engines as containing a manual shutoff valve, regulator, low-pressure switch, automatic safety shutoff valve, automatic control valve, manual leak test valve, and high-pressure manual reset switch with exceptions. Boosters or compressors, if used, shall be approved for the service intended and receivers, if used, must be stamped as complying with the ASME Boiler and Pressure Vessel Code.

Chapter 5 addresses Class 1 liquid fuels such as gasoline, gasohol, and alcohol, and liquid fuels other than Class 1 such as diesel fuel, fuel oils, jet fuel, and kerosene. The only microturbine concern in this chapter is a statement that LP-gas systems in the liquid phase must be installed per NFPA 58.

Chapter 6 presents general requirements related to lubricating systems and some requirements specific to gas turbine oil reservoirs. Technologies not employing lubricating oil reservoirs would have no interest in this chapter.

Chapter 7 addresses engine exhaust systems and clearances to combustible materials for exhaust gas temperatures less than 1400°F that would apply to microturbine installations.

Section 4 of Chapter 8 imposes control and instrumentation requirements on gas turbines. Each engine must be equipped with an automatic engine speed control, an automatic main speed control and overspeed shutdown control, a backup overspeed shutdown control that is independent from the main control, an automatic engine shutdown device for low-lubricating oil pressure (with exception), provisions for shutting down the engine from a remote location, provisions for shutting down, from a remote location, lubricating oil pumps not directly driven by the engine, an automatic engine shutdown device for high exhaust temperatures (with exception), and a means of automatically shutting off the fuel supply in the event of a flameout. The starting sequence must include a purge cycle.

Chapters 9 and 10 address operating and emergency instructions being readily accessible to personnel operating or maintaining the engine. Individuals responsible for the operation and maintenance of the engine should be familiar with the procedures.

4.5 NFPA 110, Emergency and Standby Power Systems

The emphasis of NFPA 110 is on reliability, performance, testing and maintenance. The NFPA Standards Council has ruled that NFPA 110 is primary to the NEC and NFPA 99 in these matters. NFPA 110 is much more specific with regard to generator-set installations than other codes.

NFPA developed the standard primarily for use by permitting authorities who needed a comprehensive guide beyond the various uncoordinated requirements in other codes. It addresses only the generator set and transfer switch. This standard was under contentious development for almost a decade, and any changes proposed for additional equipment can expect to be challenged.

The standard covers performance requirements for power systems (power sources, transfer equipment, controls, supervisory equipment, and all related electrical and mechanical auxiliary and accessory equipment) providing an alternate source of electrical power to loads in buildings and facilities in the event that the primary power source fails.

Section 2-3. Classifications of Emergency Power Supply Systems (EPSSs)

The standard classifies EPSSs as Types, Classes, Categories, and Levels.

Type indicates the maximum time in seconds allowed before the EPSS assumes the load. Thus, for a Type 10, the system must be fully operational within 10 seconds.

Class indicates the minimum time in hours that the EPSS will operate without refueling. Class 2 represents a system designed to operate for 2 hours.

Level defines the importance of the installation to life safety. Level 1 defines requirements for applications where failure could result in serious injury or loss of human life. Level 2 defines applications that are less critical to life. Level 3 refers to all others. No requirements for Level 3 are in the standard.

Levels 1, 2, and 3 are roughly equivalent to Emergency, Legally Required Standby, and Optional Standby in the NEC.

Unique to NFPA 110 is the requirement for prototype testing of the generator set. The supplier must show proof of performance under normal and adverse conditions before installation; this avoids problems otherwise not discovered until the installation startup, or later.

The standard requires about a dozen visual safety and shutdown indications at the generator set. It also calls for remote audible alarm for any of the conditions. It calls for prealarms where early attention might avoid a system shutdown.

During testing the system must perform all functions with results observed and recorded. Paragraph 5-13.2.5 calls for a two-hour full nameplate kW load test. The test need not be at rated power factor if the factory test was at rated power factor. Immediately after the load test and a five-minute cooldown, the system must demonstrate that it can pick up full kW load in one step.

4.6 ASME B133.8, Gas Turbine Installation Sound Emissions

This standard gives methods and procedures for specifying the sound emissions of gas turbine installations for industrial, pipeline, and utility applications. Included are practices for making field sound measurements and for reporting field data. This standard can be used by users and manufacturers to write specifications for procurement, and to determine compliance with specification after installation.

Some microturbine manufacturers have used this standard as a baseline for their product's noise profile. As it was originally written for larger gas trubine systems, however, the allowable thresholds outlined in this standard may be higher than those required by a municipal authority in a commercial or multi-unit residential setting.

5.0 Interactions Between Microturbine Generator-Sets and Other Building Systems, Structures, or Safety Issues

Issues that may attract the attention of local building permit authorities include fire protection, egress, ventilation, electrical shock protection, and fuel supply. The principal codes that apply are outlined in this chapter. Figure 5.1 presents the most common installation requirements a microturbine generator set may be subject to in a commercial setting.

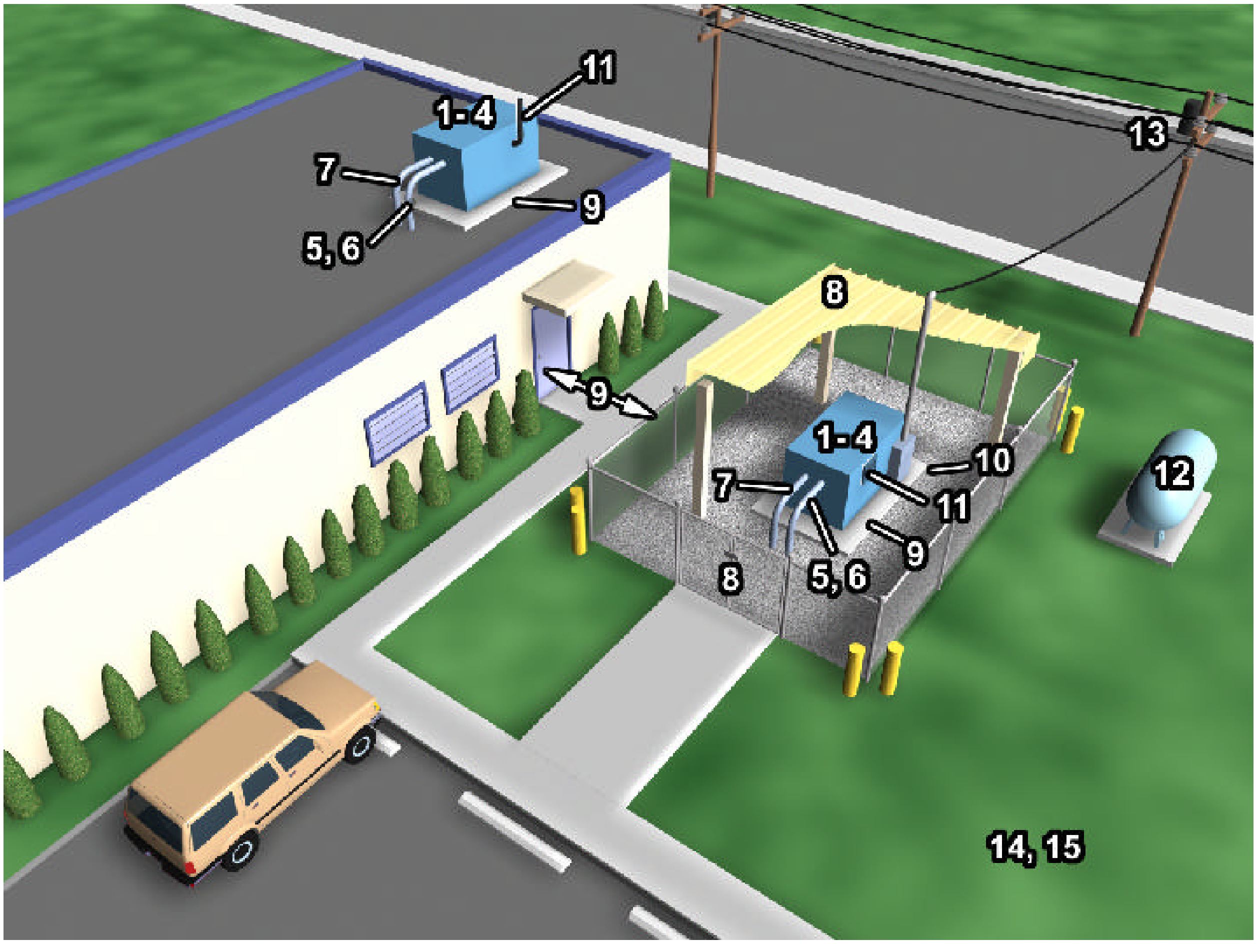

Figure 5.1. Typical Installation Requirements for Microturbine Generators in Commercial Settings

Legend

1. Component or OEM manufacturing and system integration: relevant standards from ANSI, ASHRAE, ASME, ASTM, EGSA, IEEE, NEMA, UL
2. NFPA 37, sections 8-4.1-2, combustion gas turbines must be installed with (1) an automatic main speed control and overspeed shutdown control, (2) a backup overspeed shutdown control independent from #1, (3) automatic engine shutdown device for low lubricating oil-pressure (exempt when unit is constantly attended), (4) remote engine shutdown capability, (5) remote lubricating oil pump shutdown capability, (6) remote shutdown capability for high exhaust temperatures, and (7) automatic fuel shutoff during a flameout. Additionally, the turbine starting sequence "shall include a purge cycle that produces a nonflammable atmosphere in the turbine and exhaust system prior to introduction of the fuel." (section 8-4.2)
3. NFPA 37, section 4-4.3, unattended engines shall have both a zero governor-type regulator installed AND an auxiliary shutoff valve installed ahead of any flexible connector to other controls.
4. NFPA 37, sections 6-2.1-4, requirements for gas turbines utilizing an oil lubrication system.
5. All fuel gas systems utilizing service pressures under 125 psig must be installed and operated in accordance with NFPA 54, the National Fuel Gas Code. Fuel piping must be steel or other metal, and in compliance with NFPA 30, Flammable and Combustible Liquids Code. Piping protection is outlined in MSS SP-69, Pipe Hangers & Supports - Selection and Application.
6. All pressure-boosting equipment must be certified (by stamp) for design, construction and testing according to ASME Boiler and Pressure Vessel Code, Section VIII, Division I.
7. NFPA 37, section 3-5.3.1-3, all wiring and batteries must be protected from arcing and shorting. Note: all wires, with the exception of ignition or microprocessor wiring and thermocouples, must be stranded annealed copper.
8. Enclosure - although NFPA 37 does not specifically address enclosures, the local building inspector will probably require (1) the cabinet to meet NEMA standards for explosion-proof enclosures, and (2) the integrated unit (prime mover, generator, pipes and wires and all controls & valves) to be protected from natural elements (wind, sun, precipitation, detritus) and vehicular impact.
9. NFPA 37, section 3-1.4.1 (outdoor installations): unit must be a minimum of 5 ft. from any combustible walls and bldg. openings. Also NFPA 37 section 3-2, foundation to be made of non-combustible materials.
10. NFPA 37, section 3-1.3.1, same minimum space (5 ft.) and foundation requirements as outdoor installations.
11. ASHRAE Handbook -- Fundamentals (1993) is recommended reference for design of exhaust air discharge system.
12. All LP gas systems (liquid or vapor phase) must be installed in accordance with NFPA 58, Standard for the Storage and Handling of Liquid Petroleum Gases. The Flammable and Combustible Liquids Code, API (American Petroleum Institute) 620, Design and Construction of Large Welded Low-pressure Storage Tanks, may also apply.
13. Grid Interconnection (standard currently under development by IEEE SC 21, Richard DeBlasio, chair)
14. Local zoning ordinances (definition of hazardous materials and relation to residential zones, distance to property line and rights-of-way, access by local fire and safety authorities, etc) may need to be consulted in some areas.
15. Fire Protection - Local building inspectors will require a fire risk evaluation be performed for each installation with respect to design, layout, and operating conditions of the unit. From that analysis the inspector may require any or several of a variety of fire protection systems (portable vs. fixed systems, foam or gaseous extinguishers, automatic sprinklers or dry chemical fire suppression systems).

5.1 NFPA 70-99, National Electrical Code

The purpose of the National Electrical Code (NEC) is the practical safeguarding of persons and property from hazards arising from the use of electricity. It covers installations of electric conductors and equipment within or on public and private buildings or other structures and conductors and equipment that connect to the supply of electricity. Historically, it has not controlled installations under the exclusive control of electric utilities for the purpose of communications, metering, generation, control, transformation, transmission, or distribution of electric energy. Such installations shall be located in buildings used exclusively by utilities for such purposes, outdoor on property owned or leased by the utility, on or along public highways, streets, roads, or outdoors on private property by established rights such as easements.

Many NEC requirements, important to on-site power, lie buried in articles not obvious by their titles to have relationship to generators. The NEC does not have an article on portable power sources, yet requirements exist in Articles 210-Branch Circuits, 230-Services, 240-Overcurrent Protection, 250-Grounding and 305-Temporary Wiring. Article 517 has important requirements for emergency systems in health care facilities.

Because on-site power must be compatible with utility-furnished power, many of the requirements of other articles also apply to on-site power. For example, Article 250-5 tells what systems must be grounded. These requirements apply, with certain listed exceptions, regardless of the ownership of the power-generation unit.

5.1.1 Article 700, Emergency Systems

Article 700 has five parts. Most important to the emergency power source are Parts A, General, and C, Sources of Power. The following items are of particular importance to onsite generators:

- Article 700 covers emergency systems that are legally required and classed as emergency by the governmental agency having jurisdiction or by other codes (hospitals, public facilities, mission-critical infrastructure such as air traffic control towers, etc.)

- Tests at maximum anticipated load must be witnessed, performed periodically, and a written record maintained.

- Other loads (including peak shaving) can be served if an automatic load management system ensures adequate emergency power.

- Automatic transfer switches must prevent inadvertent interconnection of normal and emergency sources (but can be bypassed).

- Audible and visual signals must indicate (1) any disturbance of the emergency power source, (2) that the battery is carrying load, (3) that the charger is not functioning, or (4) that a ground fault exists.

- In the event of an emergency, current must recommence within 10 seconds and can be from storage battery, generator set, uninterruptible power supply (UPS) system, a separate service, or individual equipment for emergency illumination.

- A generator set driven by a prime mover must have automatic or "black" start capability with a minimum of 2 hours full-load fuel supply on-site, unless there is a low probability of simultaneous failure of both the fuel delivery system and the electric utility.

- A starting battery must have an automatic charger independent of the generator set. A 15-minute time delay is required before shutdown of the set.

5.1.2 Article 701, Legally Required Standby Systems

Article 701 refers to applications less critical to life, such as heating and refrigeration systems, communications systems, and industrial processes. The NEC itself does not require standby systems, but outlines the requirements should some other authority specify one. This generally includes illumination and/or power. The requirements are somewhat less stringent than those for Article 700.

A major difference between Article 700 and 701 is that 701 does not require standby circuits to be in separate raceways. It does not require any indication for ground faults, and it allows 60 seconds to start the standby power system, rather than the 10 seconds required by 700-2.

5.1.3 Article 702, Optional Standby Systems

Article 702 briefly addresses standby systems intended to protect private property, where life safety does not depend upon the performance of the system. Typical installations include industrial and commercial buildings, farms and residences. The note specifically mentions heating and refrigeration, data processing and communication systems, and industrial processes. Only permanently installed equipment applies; it does not apply to portable generator sets.

The equipment is required to simply have sufficient capacity to supply the loads intended for simultaneous operation. It does require a transfer switch. Signals are required, where practicable, for showing derangement of the source and the successful assumption of the load. Article 702 does not require any testing or keeping of records at installation or periodically afterward.

5.1.4 Article 705, Interconnected Electric Power Production Sources

Article 705 covers installation of one or more electric power production sources in parallel with a primary source of electricity such as a utility or on-site electric power source. The code addresses some issues related to grid-connection but these requirements were not developed around microturbine technology and cogeneration applications. Efforts to establish uniform and consistent requirements for protective features specific to microturbine and other DG technologies that electric utilities would accept should focus on this code.

705-12, Point of Connection Requires interconnection at the service disconnecting means. Two exceptions apply. One, if the system qualifies as an integrated electric system and complies with all provisions of Article 685. Two, if the system non-utility sources total more than 100kW or more than 1000 volts. The second exception also requires assured maintenance and supervision and protective safeguards.

705-22, Disconnect Device Requires an accessible disconnecting means for each power source. (Utilities may require that this device be accessible to linemen and may require that the on-off position of the device be visibly verifiable.)

705-40, Loss of Primary Source Requires that upon loss of the primary power source the on-site source automatically disconnect from the primary source. It shall also not reconnect until the primary source returns.

5.1.5 Article 445, Generators

Article 445 has few if any requirements that most generator manufacturers do not meet with a standard product. It has the usual requirements for enclosure, protection of live parts and nameplate markings. It does require over current protection but allows a wide choice of methods including inherent protection.

5.1.6 Other Articles

305-6(a) Ground Fault Circuit-Interrupters (GFCI) Temporary wiring requires GFCI for receptacles. The exception, however, exempts portable or vehicle-mounted generators not more than 5 kW, provided both lines are insulated from the frame and all rounded surfaces. The system must have an equipment ground. Some authorities, including some generator set manufacturers, question the safety of an ungrounded system, however this section permits it.

250-5(d), Separately Derived System. This section requires grounding a separately derived system meeting the requirements of 250-5(b). A generator may or may not be a separately derived system.

A fine-print note explains that an on-site generator is not separately derived if the neutral is solidly interconnected to a service-system supplied neutral. Such generators should not be separately grounded. Other generators are separately derived and must be grounded if they can be grounded at 150 volts or less to ground or supply 480/277 volts.

517-65(b). Requires the alternate source of power to be a generator set located on the premises. In this case the NEC does not depend on any other code to require an emergency system and a generator set. Similar requirements are in other sections of Article 517 for other health care facilities. Strictly speaking, Articles 480-Storage Batteries and 690-Solar Photovoltaic Systems also concern on-site power sources. We will not try to cover those articles. Those systems are outside the scope of this publication.

5.2 NFPA 101, The Life Safety Code

This code deals with life safety from fire and similar emergencies. It addresses construction, protection, and occupancy features necessary to minimize danger to life from fire, including smoke, fumes, or panic. A minimum criterion for the design of egress facilities to permit prompt escape from buildings has been established, along with other considerations related to life safety.

Chapter 5, Means of Egress

Chapter 5 of the Life Safety Code is the chapter most pertinent to microturbine product developers. Section 5-9 outlines the general requirements for emergency lighting; 5-9.2.1 requires emergency illumination for a period of 1.5 hours. Illumination must be an average of 1 foot-candle; illumination may decline to 0.6 and 0.06 at the end of the 1.5 hours.

The section refers to NFPA 110 for installation, testing, and maintenance of the generator set. The standard mentions only emergency lighting and exit signs. (It refers to other standards for fire detection equipment, fire alarms, elevators, and escalators. Those standards frequently will call for fire detection, alarms, and one elevator to be on the system.)

Chapters 8-30 tell whether emergency lighting is required for each specific occupancy. For example, in Chapter 10, New Educational Occupancies, Section 10-2.9 requires emergency lighting in all interior stairs, corridors, and normally occupied spaces.

In general, schools, most health care facilities, places of assembly, correctional institutions, hotels, dormitories, apartment buildings, and certain mercantile buildings require emergency lighting of means of egress.

5.3 Fuel Gas Codes

Of all the safety codes, these are some of the most necessary. They rank with the NEC in their importance in saving lives.

5.3.1 International Fuel Gas Code (IFGC) 1997

This code was developed to supplant national fuel gas codes and is recognized by the three regional building code (BOCA, ICBO, SBCCI) organizations in the United States. As of January 1, 2000, this will replace the U.S. National Fuel Gas Code (NFPA 54, from ANSI Z223.1).

The IFGC applies to the installation of fuel gas piping systems (design, materials, components, fabrication, assembly, installation, testing, inspection, operation, and maintenance), equipment fueled by gas (installation and combustion), and “related accessories” (ventilation air and venting) for

- systems using gas at an operating pressure of 125 psi or less (covering all microturbines)
- LP gas piping systems operating at 20 psig (gauge) or less
- flammable gas-air mixtures operating at 10 psig.

The code specifically does NOT cover:

- portable LP gas equipment (unless connected to a fixed piping system)
- farm equipment
- raw material (feedstock) applications
- oxygen-fueled cutting and welding systems
- industrial acetylene and acetylenic compounds, hydrogen, ammonia, carbon monoxide, oxygen, and nitrogen
- industrial fuel processing (petroleum refineries, pipeline compressor/pumping stations, refinery tanks, natural gas processing plants)
- chemical plants where flammable or combustible liquids/gases are used in or created as a byproduct of a chemical reaction
- liquid natural gas (LNG) installations
- power plants
- “proprietary” (utility-owned) items
- temporary LP gas systems at a construction site
- vehicular LP and natural gas systems
- systems operated by gas LDC
- general building design and construction.

It is vitally important to note that Section 108.7.2 gives code officials the authority to disconnect any energy source supplied to a building (or other structure regulated by this code) that is deemed “hazardous or unsafe.” Written notice gives the building owner 24 hours to disconnect, and, in the case of immediate “danger to life or property,” the code official can immediately disconnect without prior notice.

Section 304, Combustion, Ventilation and Dilution Air Applies when 1) gas-fueled equipment is installed inside a building, and 2) the equipment requires air for combustion, ventilation or dilution of flue gasses from within the building. Direct venting to the outside overrides this section.

Chapter 4, Gas Piping Installations Chapter 4 establishes criteria for the minimum/maximum pipeline sizes for a given appliance, construction materials, shut-off valve locations, metering devices, etc. There is nothing in this section that specifically prohibits the installation of a microturbine unit.

Chapter 5, Chimneys and Vents This section covers the installation, maintenance, repair, and approval of factory-built chimneys, chimney liners, vents, connectors, and masonry chimneys. Every fuel-burning appliance is required to discharge all combustion products to the outdoors. Section 501.8 lists exempted equipment, of which microturbine units do not qualify (e.g., clothes dryers, cooking ranges, refrigerators, counter appliances, etc.)

Microturbines, if subjected to this section, will be declared a category III or IV appliance. In residential applications, the venting system would default to the manufacturers’ listed equipment. In commercial or industrial applications, a chimney, ventilating hood, and exhaust system all would be required.

Chapter 6, Specific Appliances

Section 615.1, Engine and Gas Turbine-Powered Equipment, requires that permanently installed equipment powered by internal combustion engines and turbines be installed in accordance with the manufacturer’s installation instructions and in accordance with NFPA 37 (Stationary Combustion Engines and Gas Turbines).

5.3.2 NFPA 54, National Fuel Gas Code

This is the governing code used by many local gas utilities and officials of federal, state, and local governments to judge the acceptability of fuel-gas installations. Many appliance manufacturers as part of their certified installation instructions also reference the code.

5.3.3 NFPA 30, Flammable and Combustible Liquids Code, and NFPA 58, LP-Gas Code

These two standards address the storage and handling of fuel liquids and, as such, do not impact the first-generation microturbine products.

5.3.4 International Mechanical Code - 2000

The International Mechanical Code regulates and controls the design, construction, quality of materials, erection, installation, alteration, repair, location, relocation, replacement, addition to, use, or maintenance of mechanical systems that are permanently installed and utilized to provide control of environmental conditions and related processes within buildings. The owner or agent shall be responsible for maintenance of mechanical systems. To determine compliance with this provision, the code official shall have the authority to require a mechanical system to be reinspected. Code officials should be educated on microturbine application and operation to minimize re-inspections.

Section 920 requires that gas turbines, including fuel storage and piping, meet the requirements of NFPA 37. Permanently installed equipment powered by the turbine must be installed in accordance with the manufacturers installation instructions and in accordance with NFPA 37.

Chapter 12 provides requirements for hydronic piping systems that are a part of a heating system and requires that potable hot water systems meet the plumbing code. Certain CHP installations may involve these requirements. Chapter 13 governs the installation, modification, and maintenance of fuel-gas piping systems. The applicability of this code to piping systems extends from the point of delivery to the connections with each utilization device and includes the design, materials, components, fabrication, assembly, installation, testing, inspection, operation, and maintenance of such piping systems. NFPA 54 is referenced for testing, inspecting, and purging gas piping systems.

6.0 Third-Party Testing and Certification

Until a national consensus standard is available for microturbines, developers can employ third-party testing organizations to certify the safety and operability of their product. Test results and design specifications are compared against a suite of existing codes and standards related to the product.

The drawback to this method is twofold: 1) without a national standard referenced in the model codes, every local code jurisdiction can require a battery of additional tests and design reviews, or may not permit the unit at all; and 2) education of code officials lasts only as long as that official in that office.

This chapter provides brief outlines of the most common testing and certification organizations in the United States.

6.1 CSA International

CSA International (formerly the American Gas Association Certification Labs) provides product certification, management systems registration, and information products. The organization is a Nationally Recognized Testing Laboratory (NRTL) by the U.S. Occupational Safety and Health Administration (OSHA). Certification is recognized by federal, state, provincial, and local authorities.

Certification options include the following:

Category Certification—Manufacturer arranges the tests, at own facility or at another approved facility. Manufacturer documents the results and determines whether the product meets the necessary requirements.

Shared Certification—Manufacturer performs the testing and prepares the Certification Report, which is then reviewed by CSA. CSA examines the product, reviews and validates the data, and may spot-check the testing process before granting the appropriate certification.

Witness Testing—Products are tested at manufacturer's facility by own staff, but in the presence of a CSA International representative. Based on the results of the testing, the CSA International representative then prepares the Certification Report and issues the Certification Letter.

Model Certification—Manufacturer sends product samples to CSA International for testing at its laboratory. CSA International then writes the Certification Report and, if the product qualifies, issues the certification.

6.2 Intertek Testing Services

Intertek Testing Services Scania, formerly known as the Electrical Testing Laboratory, provides independent third-party commodity sampling, inspection, testing ,and related marine surveying services to the petrochemical, fertilizer, coal, mineral, agricultural, and related industries.

ITS Quality Systems tests electrical and electronic goods from toys to telephones to appliances and medical equipment for product safety, electromagnetic compatibility, and both absolute and relative product performance. ITS also inspects and tests textiles, clothing, carpets, and consumer. The lab also provides assessment and registration services to the ISO-9000, QS-9000 (automotive), and the ISO-14000 (environmental) standards.

6.3 Hartford Steam Boiler

The Hartford Steam Boiler Inspection and Insurance Company (HSB) is the world's oldest (circa 1866) and largest insurer of power, process, and production equipment. The organization provides the following services:

ASME Code Inspection Services—An Authorized Inspection Agency (AIA) accredited by the American Society of Mechanical Engineers (ASME) for the inspection of boilers, pressure vessels, nuclear components and process and power plants. Services also include Pressure Vessel and Piping Design, Finite Element Analysis, and Quality Assurance Program Development.

Department of Transportation Services—HSB offers assistance in complying with U.S. Department of Transportation and Canadian Transport Commission regulations for tank trucks and other devices/cylinders used in over-the-road and rail transportation.

International Codes and Standards Services—Both local and international codes and standards consulting, including inspection and technical training services.

Third-Party Inspection Services—HSB's Technical Resource Support Group ensures that the manufacture and/or installation of equipment by vendors meets the appropriate standards and specifications.

Pressurized Equipment Testing—HSB's Pressure Equipment Technologies provide inspection surveys, testing, and condition evaluation of critical powerhouse equipment including boilers, deaerators, and pressure vessels. The surveys evaluate the physical conditions of the equipment and provide a detailed report with outlined recommendations for corrective actions and life-expectancy projections.

6.4 Underwriters Laboratories Inc.

Services available from Underwriters Laboratories Inc. are detailed in Chapter 2 of this report.

6.5 National Evaluation Service

The National Evaluation Service, Inc. (NES) is an independent, not-for-profit organization that conducts a voluntary program of evaluation for building materials, products and systems. NES produces technical reports that describe a building construction material or product, together with a list of conditions necessary for compliance with each of the model codes, as promulgated by Building Officials and Code Administrators International, Inc. (BOCA), International Conference of Building Officials (ICBO), and Southern Building Code Congress International, Inc. (SBCCI) as well as the International Codes of the International Code Council (ICC).

The National Evaluation Service is a member of the World Federation of Technical Assessment Organizations (WFTAO), founded to accelerate the dissemination of technical information regarding performance testing and certification of new technologies. The organization's members represent 14 countries, including Australia, Brazil, Canada, Denmark, France, Hungary, Israel, Italy, Japan, New Zealand, South Africa, Spain, the United Kingdom and the United States.

7.0 Other Barriers to Microturbine Product Acceptance

Potential barriers to the acceptance of microturbine products exist in current regulations, codes, and standards in four primary areas: emissions control, grid interconnectivity, zoning, and noise control.

7.1 Emissions Control

Regulations for the control of emissions are in place at federal, state, and local levels.

7.1.1 Federal Regulations

The Clean Air Act (1963) and its amendments (1965, 1967, 1970, 1977, and 1990) provide the critical statute for restrictions on electric generation technologies. Title I establishes national ambient air quality standards (NAAQS) that prescribe the maximum permissible concentration of pollutants allowed in ambient air. Specifically, the Act requires the U.S. Environmental Protection Agency (EPA) to establish standards for six criteria pollutants:

- carbon monoxide (CO)
- nitrogen oxides (NO_X)
- sulfur dioxide (SO_2)
- particulate matter (PM)
- ozone
- lead

In general, the responsibility for reducing air pollution levels has been assigned to the states. Each state is required to develop a State Implementation Plan (SIP) providing for the implementation, maintenance, and enforcement of measures to attain the ambient air standards by the deadlines prescribed by the Clean Air Authority (CAA). The EPA has oversight authority for each state's SIP and may direct a state to revise its SIP if necessary.

Two elements that a SIP must contain are federal New Source Performance Standards (NSPS) and New Source Review (NSR) rules. The NSPS specify maximum pollutant emission rates for various processes, including combustion equipment. The EPA has assigned such performance standards for SO_2, NO_X, and PM. NSPS are based on the level of control that can be achieved by the best demonstrated technology. NSR rules govern the permitting of new emissions sources and are triggered if a new source emits or has the potential to emit at an annual rate specified by the NSPS.

NSR rules distinguish between attainment and nonattainment areas with less stringent Prevention of Significant Deterioration (PSD) rules applying to attainment areas. The trigger for PSD rules is 250 tons/year for any regulated pollutant. Nonattainment areas are differentiated in classes based on severity of ambient pollutant concentrations: marginal, moderate, serious, extreme, and severe. NSR thresholds for nonattainment areas are indicated in Table 7.1.

To construct and operate a new power plant or DG facility (or to make major modifications to an existing plant) within a nonattainment area, the owner needs to obtain a permit from the state environmental agency if NSR levels are exceeded. The NSR process requires the owner to analyze alternative locations, sizes, production processes, and control techniques, and to demonstrate that the plant benefits outweigh its environmental and social costs. Facilities also are required to have control technology that meets the standard for lowest achievable emission rate (LAER). The control technology required to meet LAER is established by each state on a case-by-case basis for each emission source as it is permitted.

Furthermore, the owner of the plant is required to purchase offsets for each criterion pollutant that is in nonattainment. The EPA requires that emission offsets provide a positive air quality benefit to the area. Owners are therefore required to obtain more than one offset for each unit of pollutant emitted. The offset ratio depends upon the extent to which the region is in nonattainment. This offset requirement has promoted the establishment and trading of emission reduction credits for NO_X and volatile organic compounds (VOCs) among industries in 12 states.

The process for reviewing new facilities is slightly different in attainment areas. In these areas, owners also are required to obtain a permit to construct and operate new plants (or to make major modifications to existing plants), to ensure that new pollution sources do not make the region slip into nonattainment. These PSD permits require a review of the air quality impacts of the proposed facility.

Table 7.1. NSR Thresholds for Nonattainment Areas

Pollutant	**Area Designation**	**Threshold (Tons per Year)**
Ozone precursors (NO_x, VOC)	Marginal	100
	Serious	50
	Severe	25
Inhalable Particulate Matter (Pm10) and Pm10 Precursors (NO_x, SO_2, VOC)	Moderate	100
Carbon Monoxide	Serious	70
Nitrogen Oxides, Sulfur Dioxide	Any nonattainment area	100

New plants are required to install best available control technology (BACT) for all pollutants regulated under the CAA. The control technology required to meet BACT is established by each state on a case-by-case basis for each emission source.

Historically, less stringent controls apply to existing electric utility facilities in attainment areas due to grandfathering statutes. This provides clear advantages when competing with new sources that require specific emission controls as specified by NSPS (Biewald et al. 1998). This situation may be changing as a host of new regulatory initiatives could result in more stringent controls for existing facilities, especially coal-fired facilities. These controls could have a significant influence on the cost of power from coal-fired facilities, making them less attractive in a competitive marketplace.

A DG project, particularly one based upon hydrocarbon combustion such as a microturbine, could be impacted by a suite of other federal laws, including

- Clean Water Act (1987)
- Resource, Conservation and Recovery Act (1976)
- Occupational Safety and Health Act (1970)
- Toxic Substances Control Act (1976)
- Endangered Species Act (1973)
- Coastal Zone Management Act (1972)
- Historic Sites Act.

7.1.2 State Regulations

Each state is responsible for implementing programs that conform to the mandates of the federal CAA and associated amendments. Progressive states with areas experiencing severe air quality problems (e.g., Los Angeles) have implemented even more stringent air quality standards than current federal mandates. Regardless of the criteria, the responsibility for implementation and enforcement falls on air pollution control officials at the local level.

The potential for diverse state requirements can lead to inconsistent requirements that pose barriers or opportunities for microturbines. Differing requirements could allow more centralized power generation technologies (combined-cycle gas turbines) to choose which state had the least stringent requirements, while the power could be transmitted to the demand location. Conversely, inconsistent or uncertain requirements might be an added incentive for construction of distributed generation capacity that has low air contaminant signatures (renewables, fuel cells) not subject to state permitting regulations.

7.1.3 Local Environmental Regulations

Based on the projected emission signatures of microturbines, it is anticipated that federal regulatory requirements for NSR will not be triggered; local agencies will therefore be the primary regulatory authority overseeing microturbine installations relative to environmental concerns. Depending on the attainment status of the local area, permitting thresholds specified by Air Pollution Control Districts (APCDs) may limit the operating schedule or emission limits of a microturbine if a predetermined power rating is exceeded. In addition, control technologies may be required. If the permit thresholds are not triggered, microturbines will be exempt from local air quality regulations. It is likely that permitting requirements will change over the next several years. However, these changes may broaden the regulatory envelope to include microturbines.

7.1.4 Emission Signature of Microturbines

Of the different air and liquid (e.g., contaminated cooling water, oil seepage) emissions associated with microturbines, air emissions will have the greatest influence on a project's permitting. NO_x and CO_2 emissions are the critical emission categories, given their magnitude for conventional electric generation technologies. Although SO_2 also is an important emission category for traditional electric utilities, SO_2 emissions are expected to be negligible in microturbines.

The air emission signatures of selected DG technologies are shown in Table 7.2. These values are based on theoretical calculations or laboratory source testing (Cler and Lenssen 1997; NREL 1995). The actual emission signature for each technology is design-specific and dependent upon various locational criteria.

Fuel cells, with their electrochemical process of producing electricity, have the cleanest emissions profile, followed by microturbines and reciprocating engines, respectively. With the exception of CO_2, microturbines also exhibit generally low emissions for all classes of regulated pollutants.

Table 7.2. Emission Profiles of Selected DG Technologies

Distributed Generation Technology	Pollutant, lb/MM Btu			
	NO_x	CO_2	CO	SO_2
Microturbine	0.4 - 0.21	119	0.11	0.0006
Internal Combustion Engine (Gas)	3.1	110	0.79	0.015
Internal Combustion Engine (Diesel)	2.8	150	1.5	0.3
Fuel Cell	0.003	1	--	0.0204
Source: NREL (1995); Cler and Lenssen (1997)				

7.2 Grid Interconnectivity

The most contentious and expensive portion of any microturbine installation is the unit's relationship with the local electrical distribution system and the end-user's current electric service provider. Most microturbine installations are not currently designed to provide 100% of peak load, and the owner/ operator of the local electrical distribution company, or LDC, is expected to allow the microturbine to connect for grid-parallel operation and to provide backup service, should the unit fail. (In the vast majority of customer cases today, the LDC still owns the generation capacity serving that customer, as well).

The prospect of introducing thousands--or hundreds of thousands--of independently operated electricity-generating units onto distribution feeders gives rise to a variety of safety, system stability, and competitive issues. IEEE SCC21 has convened under Richard DeBlasio of NREL to develop P1547, "Standard for Distributed Resources Interconnected with Electric Power Systems." The consensus standard is expected to be completed by 2002 and will provide performance requirements for safety and system (grid) stability, including

- prevention of out-of-range voltage, frequency, harmonics and power factor
- disconnection for faults
- prevention of transient magnification
- limitation of DC injection
- limitation of voltage flicker induced by the generator
- prevention of disruptions on the utility system
- provisions for isolation
- integration with existing grounding system
- synchronization
- control of directional power flow
- prevention of islanding beyond point of common coupling
- prevention of re-energization beyond the point of common coupling
- detection of loss of grid: voltage or frequency disturbances

- single-phase fault detection for three-phase interconnection
- feeder reclosing coordination considerations
- regulators: power system and distributed generator voltage regulators, potential overvoltage conditions of islanded operation
- harmonics
- combination of harmonics and current imbalance
- voltage flicker
- islanding
- characteristics and properties of distribution transformers
- technology documentation
- electric power system documentation.

7.3 Zoning Ordinances

Zoning ordinances were developed to provide minimum standards for protection against incompatible uses on adjacent properties. In addition, zoning ordinances promote the health, safety, and general welfare of the inhabitants of a given municipality, or protect and conserve the value of the property within that city. For this purpose, the height, number of stories, size of buildings and structures, size and width of lots, the percentage of lot that may be occupied, the size of yards, courts and other open spaces, parking structures, the density of population and the location and use of buildings, structures and land for trade, marine business, industry, agriculture, residence, or other purposes may be regulated.

Although zoning ordinances generally do not address either standby or continuous-duty power-generation systems in residential or commercial districts, it is possible that the advent of widespread DG systems in residential zones will require a review of the zoning literature, particularly what constitutes a "prohibited use" ("any use which is injurious, noxious or offensive by reason of the emission of odor, fumes, dust, smoke, vibration, noise, lighting or other cause"). Some local zoning ordinances are much more intimately involved in local building codes, including egress and fire protection measures. For this reason, it is possible that municipal planning departments will perceive the DG unit as a substantial alteration or addition to the existing use of a building, and require a zoning review as part of the permitting process.

The Building Codes Assistance Project (BCAP) has created an online forum for discussion of residential and commercial model energy codes. The purpose is to facilitate exchanges of information relating to energy codes. To subscribe, send an email to: bcap_energycodes_forum@ase.org. with the word SUBSCRIBE in the body of your message.

7.4 Noise Level

Noise level is a municipal issue and varies by jurisdiction. In general, this should not present a hurdle for microturbines. As an example, Capstone's Model 330 is rated at 65 dBA at 10 meters, while many outdoor sections of air conditioners and heat pumps are rated at 78 to 82 dBA.

8.0 Conclusions and Recommendations

The review of standards and codes documented in this report forms the basis for the conclusions and recommendations presented in this chapter.

It appears that microturbine generator sets can comply with the existing model codes for installation and operation, despite the lack of any reference to their technology by name. However, as detailed in Chapter 2, as additional microturbine products enter the marketplace it will become increasingly important that they are referenced—by name—in the model codes, a process that must begin with a manufacturing or system integration standard. Several vendors have already approached Underwriters' Laboratories for certification of their product under UL 2200. This will give the industry certification for electrical safety and ease the local permitting process in many jurisdictions. But UL 2200 is a standard, not a model code. The National Electrical Code, Mechanical Code, International Fuel Gas Code, Life Safety Code, and International Building Code must all eventually be modified to reference, if not microturbines, then onsite power generation systems that include microturbines.

Over the past several years the fuel cell community has been successful in developing performance and installation standards that will be referenced in the year 2000 editions of the model codes. This effort was coordinated by the U.S. DOE, and can be used as a roadmap for other distributed generation systems.

Of equal importance, the entire industry of advanced, onsite power generation technologies need performance and reporting standards that can be referenced by federal, state and local authorities for operation permits, emissions evaluation and credits and energy-efficiency incentives. To this end, the U.S. Department of Energy should investigate support for a microturbine-specific performance standard , and for those applications most relevant to the emerging DER market--combined heat & power, premium power quality.

And despite the absence of any referenced code barriers to microturbines, a general lack of education among code officials on the differences between DER installations and traditional backup generators, is in fact hampering their deployment. A general State education program, providing code officials with hands-on experience and an opportunity to explore DER technologies before they receive a permit application, would support all stakeholders in the U.S. DER industry.

Appendix A

Selected IEEE Standards Relevant to Onsite Power Generation

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Selected IEEE Standards Relevant to Onsite Power Generation

421.1-1986 (R1996) “IEEE Standard Definitions for Excitation Systems for Synchronous Machines”

421.2-1990 “IEEE Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems”

421.4-1990 “IEEE Guide for the Preparation of Excitation System Specifications”

505-1977 (R1996) “IEEE Standard Nomenclature for Generating Station Electric Power Systems”

665-1995 “IEEE Guide for Generating Station Grounding”

666-1991 (R1996) “IEEE Design Guide for Electric Power Service Systems for Generating Stations”

803.1-1992 “IEEE Recommended Practice for Unique Identification in Power Plants and Related Facilities--Component Function Identifiers”

928-1986 (R1991) “IEEE Recommended Criteria for Terrestrial Photovoltaic Power Systems”

929-1988 (R1991) “IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems”

P929, D10 Feb 1999 “Draft Recommended Practice for Utility Interface of Photovoltaic (PV) Systems”

1046-1991 (R1996) “IEEE Application Guide for Distributed Digital Control and Monitoring for Power Plants”

1145-1999 “IEEE Recommended Practice for Installation and Maintenance of Nickel-Cadmium Batteries for Photovoltaic (PV) Systems”

1150-1991 (R1998) “IEEE Recommended Practice for Integrating Power Plant”

1159-1995 “IEEE Recommended Practice for Monitoring Electric Power Quality”

1262-1995 “IEEE Recommended Practice for Qualification of Photovoltaic (PV) Modules”

1346-1998 “IEEE Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment”

C37.90.1 “IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems”

C37.95 “IEEE Guide for Protective Relaying of Utility-Consumer Interconnections”

C62.41 “IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits”

519 “IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems”

Appendix B

EGSA Standards

Appendix B

EGSA Standards

100 SERIES STANDARDS

Under the purview of the Power Generation Components Subcommittee.

EGSA 100B-1997—Performance Standard for Engine Cranking Batteries Used with Engine Generator Sets

Contains requirements for rating, classifying, applying, installing and maintaining engine cranking batteries.

EGSA 100C-1997—Performance Standard for Battery Chargers for Engine Starting Batteries and Control Batteries (Constant Potential Static Type)

Contains requirements for voltage and temperature limits, application and accessories for charging engine cranking batteries.

EGSA 100D-1992—Performance Standard for Generator Overcurrent Protection, 600 Volts and Below

Contains performance specifications for circuit breakers, field breakers, thermostats, thermistors and other temperature detectors.

EGSA 100E-1992—Performance Standard for Governors on Engine Generator Sets

Contains classifications, performance requirements and optional accessories for generator set engine governors.

EGSA 100F-1992—Performance Standard for Engine Protection Systems

Contains performance specifications for engine control systems including temperature, level, pressure and speed sensing.

EGSA 100G-1992—Performance Standard for Generator Set Instrumentation, Control and Auxiliary Equipment

Contains requirements for generator set engine starting controls, instrumentation and auxiliary equipment.

EGSA 100M-1992—Performance Standard for Multiple Engine Generator Set Control Systems

Contains performance requirements for manual, automatic fixed sequence and random access generator set paralleling systems.

EGSA 100P-1995—Performance Standard for Peak Shaving Controls

Contains requirements for parallel operation and load transfer peak load reduction controls.

EGSA 100R-1992—Performance Standard for Voltage Regulators Used on Electric Generators

Contains application and performance requirements for generator voltage regulators.

EGSA 100S-1996—Performance Standard for Transfer Switches for Use with Engine Generator Sets

Contains classifications, applications and performance requirements for transfer switches for emergency and standby transfer switches.

EGSA 100T-1995—Performance Standard for Diesel Fuel Systems for Engine Generator Sets with Above Ground Steel Tanks

Contains application and performance requirements for diesel fuel supply systems with above ground steel tanks for diesel engine driven generator sets.

101 SERIES STANDARDS

Under the purview of the Power Generation Systems Subcommittee.

EGSA 101G-1994—Glossary of Electrical and Mechanical Terminology and Definitions

Contains definitions of terms specific to the on-site power industry.

EGSA 101N-1992—Standard Nameplate Design for Engine Generator Sets

Guidelines for the information that should be included on the nameplate of a generator set.

EGSA 101P-1995—Performance Standard for Engine Driven Generator Sets

Contains classifications of use, prime mover configuration and ratings, and performance requirements for complete generator sets.

EGSA 101S-1995—Guideline Specification for Engine Driven Generator Sets, Emergency or Standby

Guideline specification in blank form for preparing specifications for emergency or standby generator sets.

EGSA 109C-1994—Code Listing: Safety Codes Required by States and Major Cities

A listing of national and international codes and standards adopted by U.S. states and selected major cities.

Referenced Code Organizations

The National Building Codes (NBC)
Building Officials and Code Administrators International (BOCA)
4051 West Flossmoor Road
Country Club Hills, IL 60478-4981
(708) 799-2300

The Uniform Building Codes (UBC)
International Conference of Building Officials ICBO)
5360 South Workman Mill Road
Whittier, CA 90601
(213) 699-0541

The Standard Building Codes (SBC)
Southern Building Code Congress International (SBCCI)
900 Montclair Road
Birmingham, AL 35213
(205) 592-1853

The Hartford Steam Boiler Inspection and Insurance Company
One State Street
P.O. Box 5024
Hartford, CT 06102-5024
Tel: (860) 722-1866
Fax: (860) 722-5106

ASME International
Three Park Avenue
New York, NY 10016-5990
800-THE-ASME (U.S./Canada)
E-mail: ASME InfoCentral

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, PA 19103-1187

Federal Specifications (FS)
General Services Administration
7th & D Streets
Specification Section, Room 6039
Washington, DC 20407

National Fire Protection Association (NFPA)
Batterymarch Park
Quincey, MA 02269

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, Il 60062-2096

Electrical Generating Systems Association (EGSA)
1650 S. Dixie Highway, 5th Floor
Boca Raton, FL 33432

Institute of Electrical and Electronics Engineers (IEEE)
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855

Intertek Testing Services (ITS) Canada Ltd.
1055 West 14th Street, Unit 600
North Vancouver, BC, Canada V7P 3P2
Tel: (604) 984-4231
Fax: (604) 986-1205
Email info@its-pkb-vancouver.com

Appendix C

U.S. Microturbine Developers

Appendix C

U.S. Microturbine Developers

AlliedSignal Power Systems Inc.
Mark Skowronski - or code officer
2525 West 190th Street
Torrance, CA 90504
Tel 310-512-2777
Fax 310-512-1561
e-mail mskowronski@alliedsignal.com
www.alliedsignal.com/parallon

Allison Engine Company
Name of Code Officer
2925 West Minnesota Street
Indianapolis, IN 46244
Tel 317-230-2013
Fax 317-230-3562
e-mail norbert.osborn@allison.com
www.allison.com/www/product/industrial/home.html

Capstone Turbine Corp.
Name of Code Officer
6430 Independence Avenue
Woodland Hills, CA 91367
Tel 818-716-2929
Fax 818-716-9910
email mrobinson@capstoneturbine.com
www.capstoneturbine.com

Elliott Energy Systems
Richard Sanders, Vice President, Sales & Marketing
2901 Southeast Monroe Street
Stuart, FL 34997
Tel 561-219-9449
Fax 561-219-9448
e-mail drb@emi.net

Northern Research and Engineering Corp.
Code guy
39 Olympia Avenue
Woburn, MA 01801
Tel 781-935-9050
Fax 781-935-9052
e-mail sales@nrec.com
www.nrec.com/pwrwrks.htm

Teledyne Continental Motors
Name of Code Officer
1330 W Laskey Road
P.O. Box 6971
Toledo, OH 43612-0971
Tel: 419-470-3073

Williams International
Name of Code Officer
2280 West Maple Road
Walled Lake, MI 48390
Tel 248-960-2566
Fax 248-624-5345

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