Supplemental Data #3

A Review of Communications, Electrical, and Plumbing Systems Relative to Whole-House/Systems Design and Construction

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Prepared By:

Mark Nowak
Newport Partners LLC
Davidsonville, Maryland

Abstract:

The following report is a review of literature dealing with communication, electrical, and plumbing systems in homes. The main body of the report addresses standards, interactions, and specific examples where a whole-house approach has been applied to the communication, plumbing, and electrical systems of a home. The documents and other materials uncovered during the literature search are found in the attachment of this report. Special thanks to Howard Bashford and Anil Sawhney of Housing Innovations LLC for identifying and compiling the documents in the attachment.

Introduction

This report is the result of a review of the literature on communication, electrical and plumbing systems in homes. The objective was to address three main questions:

1. Are there existing performance and other standards that address the communication, electrical and plumbing systems from a whole-building perspective? This included a review of standards or guidelines from building codes and standards, as well as various voluntary industry or research programs that may be applicable.
2. Are there specific interactions, either positive or negative, that have been documented between these systems and other systems in the home?
3. Are there examples where a systems design or whole-house approach has been applied to specifically address the communication, plumbing, and electrical systems?

The documents and other materials uncovered as part of the literature search are shown in the Attachment to this report.

Whole house programs and standards

The literature reveals several key findings about electrical, communications, and plumbing systems in relation to whole-house design from a performance or standards perspective.

First, there are standards for almost every product, technology, or process used in home construction. However, these standards tend to only address a specific product or a vary narrow process. Although standards that address multiple systems or subsystems exist, they are rare.

Second, standards that do expand beyond a very narrow scope are almost always limited to one or two systems or subsystems and do not begin to approach a whole-house or systems design approach. Some notable examples are as follows:

> Building codes: In some respects, the International Residential Code, the National Electrical Code, or similar documents could claim to address the whole house. In reality, although there are some systems interactions addressed in these types of codes, mostly they are a compilation of specifications for individual systems or subsystems with very little acknowledgement of interactions. An example of how codes look at system interactions relative to plumbing, electrical, or communications are the limitations on cutting or notching of structural members. These requirements are included in codes in recognition that the structure of a home and the wiring or plumbing systems can be in competition for the same space.
>
> Standards: Standards like the ASSE 1021-2001 are intended to address some limited interactions in homes. This particular standard, Performance *requirements for drain air gaps for domestic dishwasher applications*, addresses the potential contamination of the plumbing system due to its connection to a home appliance. Other standards or documents referenced by the building codes also cover some interactions, but typically for only one or two different systems. For example, *Manual J, Residential Load Calculation*, (8th edition, published by ACCA) has become the most often referenced document for

determining building thermal loads. Manual J considers the interaction of items like hot water pipes and lighting and appliances on the building's load. However, if a designer were only responsible for the HVAC system using Manual J (as is often the case), he or she would miss many other interactions between the HVAC system and the electrical or structural systems.

Third, there are some research programs that have attempted to look at the home from a whole-house or system integration approach. These programs may represent the closest attempts to a whole-house approach to date. Several have resulted in the production of guidelines or similar requirements. Examples include:

Operation Breakthrough (see companion literature review by Newport Partners, LLC and Virginia Tech from February 2004 in *Supplemental Data #1* for a more detailed review of the Operation Breakthrough program), a HUD sponsored program from the late 1960s and early 1970s, included an activity by the National Bureau of Standards (now the National Institute of Standards and Technology or NIST) to develop performance standards for the entire home. The publication resulting from this was a set of performance standards that at least attempted to lay the foundation for a whole-house design approach by identifying requirements for each of the systems found in a home.

Another part of Operation Breakthrough that addressed systems engineering was the Optimum Value Engineering (OVE) program. This program is noteworthy in that the researchers involved in the project attempted to apply a whole-house approach to the building design. Although the framing parts of OVE eventually became its flagship items, the original approach included all of the systems and subsystems in the home.

The OVE program may be the earliest attempt to look at the home from a whole-house, methodical perspective. The researchers approached the design of the home by first optimizing the construction on a system by system basis, fashioned around an objective to minimize initial construction costs. They then evaluated the different systems and subsystems according to their impact on other systems and against other performance objectives. For example, the Energy Efficient Home (EER) program that was a follow-on to the base OVE project, introduced energy performance objectives into the program.

The effort involved in the OVE program gives some insight into the scope of the tasks required to develop a whole-house calculator. In today's dollars, the OVE program would be a multi-million dollar program. It involved the resources of the Federal government, manufacturers, builders, test labs, engineers, and others working together for several years. Despite the resources and extensive efforts involved, some of the homes did experience problems that required modifications. For example, one of the EER homes required modifications to eliminate a moisture problem. We highlight this not to be critical in any way of the original researchers, but rather to note that a whole-house approach requires a lot of information to be successful. In many cases, the information to make decisions does not exist. Despite the best efforts, a whole-house approach will not eliminate every problem but will certainly reduce the negative interactions in homes that occur when systems are designed in isolation.

A more recent program, also supported by HUD through the PATH program, is the PATH Concept Home. Under this program, the research team is looking at ways to address some of the larger interactions between major systems to enable builders to construct homes that are, among other things, more flexible and with less system entanglement than today's homes. This program is in its early stages.

Finally, one of the more-widely known programs to embrace a systems approach is the U.S. Department of Energy's Building America program. A review of this program is provided in *Supplemental Data # 2*. The Building America program, although more comprehensive than most programs, still falls short of a true whole-house approach since it is mostly focused on interactions dealing with moisture, ventilation, and energy. Some ventures into other interactions are part of the program, such as the use of advanced framing to minimize interruptions in the thermal envelope.

Interactions related to plumbing, electrical, and communications

The literature on communication, electrical and plumbing systems shows some significant interactions between these systems and other systems in homes. For the most part, the interactions are mainly related to the physical routing of these systems through the structure. This creates a negative interaction when the structural framing is cut or notched beyond acceptable limits.

Examples of other interactions found in the literature include:

- the plumbing system's (hot water) interaction with the energy system through an increase or decrease in the heating or cooling load.
- lighting, appliances, and other electrical components' interaction with the energy system through the impact on the building loads.
- appliances that use water having a potential negative impact on the plumbing system through contamination of potable water supplies.
- plumbing system interactions with the foundation design. For example the interaction between temperatures in a vented crawlspace and plumbing pipe failures, or the soils/foundation potential negative impact on certain plumbing materials.
- plumbing systems that require envelope penetrations, especially in the roof, that create durability issues.

When assessing the literature search findings, one could conclude that the communication, electrical and plumbing systems have some limited interactions with a few parts of the home. However, other than the few cited here, others that exist are not as well documented as the interaction with the structural system. The building codes have included limitations on modifications to structural systems for decades. Inspectors, builders, and others may tend to be more aware of the structural issues because they are, along with fire concerns, considered one of the more important life-safety issues.

Case studies

This section describes several cases where a builder or program has adopted a systems design approach with particular emphasis on the integration of the plumbing, electrical, or communications systems into the overall design. One interesting observation with these cases is that the persons involved tend to have their own definition of systems design. Their reasons for adopting the approach are often different. One may have energy efficiency as a major objective, others may have flexibility or cost of construction. However, each has a common understanding that there is a need to look at buildings to understand the interactions of one part or process with the rest of the home.

Operation Breakthrough (OB) and the Building America programs are two examples where government agencies have worked with builders to look at the home with systems design in mind. These programs have been discussed earlier and will only be briefly discussed here.

The OB approach might be closer to a comprehensive whole-house approach than any of the other examples we found in the literature. The OB approach paid close attention to all systems in the homes. Two of the OB core objectives were to reduce the cost of housing and increase production, which cuts across all the various systems and subsystems in a home.

At the time of OB in the late 1960s and early 1970s, the electrical and plumbing systems in homes were not nearly as elaborate as in today's homes, and the communications system was basically limited to the doorbell and phone. However, there are a few lessons from OB relative to the communications, electric, or plumbing systems. For example, several OB designs stressed items that save labor like pre-assembled plumbing trees. Likewise, some of the OB designs contained electric harnesses to allow the wiring to be pre-wired but easily rolled out in the field to minimize labor costs and interference with the structure. Some of the prefabrication designs went even further in addressing plumbing and electrical systems, again to decrease the potential negative interactions with the structure. At least one manufacturer in the program designed plumbing and utility cores into the homes to disentangle or otherwise simplify field operations.

As mentioned earlier, the Building America program is focused on energy efficiency. Some of the objectives of the program, however, do at least in part help to address the interactions of the communications, electric, and plumbing systems with other systems in the home. For example, the program promotes the benefits derived from turning the attic or crawl space into conditioned space. This directly addresses some of the concerns of the plumbing system designer who must otherwise figure out a way to protect water piping in a cold crawl space or attic.

Bob Schmitt Homes is a builder and developer in the Cleveland area that has been operating for over 50 years. Its founder and namesake early on adopted a philosophy that a home should be built in an orderly and logical manner, rather than around the trade contractor model that dominates the industry. They have spent years evaluating different technologies and processes to optimize the way they build while producing a home that has met an increasing number of performance requirements over the years.

The heart of the Bob Schmitt Homes approach is the production process which is geared toward a slab-on-grade foundation. The construction is divided into phases. The initial phase brings the home up to the point where the walls can be erected. In this phase, all of the components in the slab are constructed by the same crew, which is crossed trained on the excavation, footing, slab, and the utilities that go into the slab including the ductwork and plumbing ground works. Thus, the design and construction of the work in this phase is highly integrated.

The second phase is the framing system and surrounding components that are traditionally defined as the rough-in stage. Much of this work is completed in an on-site factory so that the electric, plumbing, and other components are all considered in the design and construction. The finish is the last phase and again cuts across a number of disciplines and products traditionally completed by separate trades in isolation.

Although Bob Schmitt Homes has been successfully employing their approach for decades, it has not been with out some downside. Early on, the company had to stay out of heavily regulated or unionized areas that frowned on their innovative approach to building. Also, in recent times, they have had to rely more on the traditional trade contractor model for some of the later phases simply because of an inability to find or retain people with the skills to work across multiple disciplines. These and similar institutional issues are summarized in the companion report of this project titled *Non-Technical Needs and Opportunities for a Whole-House Approach to Home Building*.

Bensonwood Homes is a Vermont-based systems builder. A major difference between Bensonwood and other similar manufacturers is that they produce custom homes in a factory. Perhaps more than anyone in the market, Bensonwood has embraced the open building and systems design philosophies and taken them to new levels of practical implementation.

The Bensonwood approach is built around six systems: Site, Structure, Skin, Services, Space plan, and Stuff. Most applicable to this literature review is the approach they take with regard to the plumbing, electrical, communications, and other services.

Bensonwood homes are built to keep the structure (and the other systems) separate from the services. Instead of the typical industry practice of routing pipes and wiring through the framing members, they create separate spaces where the services can be installed with little to no interference with the structure. For example, the space between the first and second floor is an open area where the trade contractors can work freely without worry about the structural system getting in their way. Bensonwood uses ceiling panels that are one of the last parts installed in the home. The panels are easily removed to offer access for repair, maintenance, and future expansion or modification of the services. A more detailed overview of the Bensonwood system is provided on their web site at www.bensonwood.com.

Conclusions regarding communication, electrical and plumbing systems

Our results from this review indicate the following:

1. There is a standard for almost every product or process used in the building of homes. This applies equally to communication, electrical and plumbing as well as other systems in

homes. However, rarely do standards cut across multiple systems or products. Instead, they tend to reinforce the present system of looking at the design of a home in a fragmented manner.

2. There are documented examples of interactions between the plumbing, electrical, and communications systems and other systems in the home. Interference with the structural system appears to be the most frequently documented interaction.
3. A few programs have embraced a whole-house design approach, but most are not comprehensive across all of the systems in a home. Likewise, a few builders have adopted a whole-house or systems design approach, but their definition of what this means varies according to their priorities or objectives. None are truly comprehensive. On the other hand, it may not be reasonable to expect a builder to adopt a comprehensive approach since our work under this project has shown that there are significant gaps in the knowledge and ability to apply such an approach. In fact, this project was inspired partly because of the lack of a good tool for a comprehensive evaluation of the systems in a home.

Attachment – Literature on Communications, Electrical, and Plumbing Systems

Communication Systems

Communication systems in the residential construction context are assumed to consist of: 1) telephone system; 2) security and fire alarm system; 3) internet connection system; and 4) home audio and video system. The following subsection lists the standards organizations, technical reports and product evaluations pertaining to these systems.

Standards Organizations

ANSI – American National Standards Institute
www.ansi.org

> ANSI facilitates the development of Standards by accrediting the procedures of those agencies that develop standards.

TIA – Telecommunications Industry Association
www.tia.org.uk

> TIA is a trade association serving the communications and information technology industry. TIA represents the communications sector of the Electronic Industries Alliance (EIA).
>
> TIA and EIA work together to produce the standards and technical documents that cover virtually every aspect of the telecommunications industry: fiber optics (including cables, connectors, field equipment, systems design, systems testing, symbols, terminal devices, tools. waveguides, closures, branching devices), facsimile equipment, cellular communications technology, data interchange transmission equipment, land mobile communications, modems, personal communications services, telephones/terminal equipment (including key systems, FCC guidelines, PBX, PBX wireless, terminals), and wire and cabling.
>
> TIA/EIA – 570-A Residential Telecommunications Cabling Standard (superseded by TIA-570-B)
>
> This document standardizes requirements for residential telecommunications cabling. These requirements are based on the facilities that are necessary for existing and emerging telecommunications services.

TIA/EIA -570-A-1 Residential Telecommunications Cabling Standard – Addendum 1 – Security Cabling for Residences (superseded by TIA-570-B)

This addendum provides recommendations and specifications for security cabling systems in residences. It contains references to national and international standards

TIA/EIA -570-A-2 Residential Telecommunications Cabling Standard - Addendum 2 - Control Cabling for Residences (superseded by TIA-570-B)

This addendum focuses on control cabling for residences, recognizing the evolving nature of residences, and the inherent limitations in adapting to changing cabling needs once the residence has been constructed.

EIA - Electronic Industries Alliance
www.eia.org

EIA provides a forum for industry to develop standards and publications in major technical areas: electronic components, consumer electronics, electronic information, telecommunications, and Internet security.

EIA Standard– Home Automation System

This Standard provides the necessary specifications for the Consumer Electronic Bus (CEBus), a local communications and control network designed specifically for the home. The CEBus network provides a standardized communication facility for exchange of control information as data among devices and services in the home. CEBus is intended to handle existing and anticipated control communication requirements at minimum practical costs consistent with a broad spectrum of residential applications. It is intended for such functions as remote control, status indication, remote instrumentation, energy management, security systems, and entertainment device coordination. A major objective of this specification is compatibility. It is intended that every implementation of CEBus be able to co-exist with every other implementation; that every device that meets this specification can communicate with all other CEBus devices; and the language used for control functions will be understood by all devices. This version includes portions of IS-60 that have not been revised as well as new ANSI approved updates.

CEA – Consumers Electronics Association
www.ce.org

CEA represents more than 1,000 corporate members involved in the design, development, manufacturing, distribution and integration of audio, video, mobile electronics, wireless and landline communications, information technology, home networking, multimedia and accessory products, as well as related services that are sold through consumer channels.

CEA – Standard 23 RF Interface Specification for Television Receiving and Cable Television Systems

This specification is intended to apply to all cable systems and to all receiving devices which may be directly connected to a cable system residential outlet, including, but not limited to, television sets, video cassette recorders, and converters.

IEEE - Institute of Electrical and Electronics Engineers
http://www.ieee.org/portal/site

A new standard from the Institute of Electrical and Electronic Engineers (IEEE) opens the world of wireless communications to inexpensive applications from sensors and switches for industrial and residential use and many others. The standard, IEEE 802.15.4(TM), provides for low-data-rate connectivity among relatively simple devices that consume minimal power and typically connect at distances of 10 meters (30 feet) or less.

Codes

NFPA – National Fire Protection Association – National Electrical Code
www.nfpa.org

Covers electric conductors and equipment installed within or on public and private buildings or other structures, including mobile homes and recreational vehicles, floating buildings; and other premises such as yards, carnivals, parking and other lots and industrial substations; conductors that connect the installations to a supply of electricity; and other outside conductors and equipment on the premises; optical fiber cable; buildings used by the electric utility, such as office buildings, warehouse, garages, machine shops, and recreational buildings that are not an integral part of a generating plant, substation, or control center.

Federal Regulations

Federal Communications Commission
ftp://www.fcc.gov/pub/Bureaus/Cable/Notices/fcc95504.wp

Telecommunications Services Inside Wiring, FCC 95-504
This requires all the telecommunications in the home to be Category 3 or better. Category 3 cables include 2 to 4 copper wires that are twisted and covered in plastic sheathing. This replaces the 4-wire telephone cable that was currently used.

Communication Materials and Systems

NAHB. (2000). Special Report: Residential Communications Wiring. NAHB Research Center.

> The conclusions and recommendations below summarize the information presented in this report.
>
> A wiring system using special telephone/data cables (Category 3 and preferably Category 5 cables) and special coaxial cable (RG-6) will meet the communication needs of most families now and in the foreseeable future.
>
> Builders have three options available for offering a structured wiring system to homebuyers.
>
> 1. Assemble a system made up from components.
> 2. Buy a system from a systems integrator.

3. Buy a system from a structured wiring system manufacturer.

A qualified contractor with trained installers will be needed.

A structured wiring system as described in this report should be all the wiring a homeowner needs for a future home automation system.

www.toolbase.org. Electrical Raceways. PATH Technology Inventory.

> Running wires through wall cavities can be a messy and cumbersome task. Electrical raceways can make the job a little easier. Electrical raceways are mounted on interior walls and encase electrical and communication wires. Raceways permit wires to be run along interior walls instead of through wall cavities. Electrical raceways can simplify the task of wiring and reduce wall penetrations that can compromise a building's thermal performance.
>
> Commonly used in commercial buildings, electrical raceways are now available for residential applications. As home wiring increases in complexity, new residential products are emerging that may make residential electrical raceways more common.

Black, W. (1998) Telecommunication Issues for Copper Wire and Cable. Copper Development Association. Presented at the Wire and Cable Focus Conference. http://www.copper.org/applications/telecomm/telecomm98.html

Coactive Networks. (2001). Enabling the Networked Home: The Coactive Connector Residential Gateway (available at www.Forbes.com IT research library)

> The Networked Home has become recognized as the next forefront of the networking revolution, where consumer technology and Internet infrastructure intersect to change the way we lead our lives. Much attention has been focused on the building blocks of this new world: Internet appliances, wireless devices, and home networking technologies. Recent attention has turned to the building block at the heart of the Networked Home: the residential gateway. As its centrality is acknowledged, the residential gateway has engendered a great deal of discussion and questions. Which technologies will it support? Where will it sit in the home? What services will it enable? Who will bring these services to the mass market? This white paper outlines a system solution that uses the residential gateway to deliver viable e-services to the Networked Home today. This solution is based upon Coactive Networks™ experience as the first company to deliver a full-service residential gateway, and the first company to deploy these consumer e-services to the mass market.

Lucent Technologies. (2004). Maximizing Value with Multi-Service Access Solutions. Lucent Technologies Inc. White Paper.
(available at whitepapers.zdnet.co.uk/0,39025945,60097421p-39000411q,00.htm last visited March 2005)

Residential and business customers need high-speed data services, along with traditional voice services. However, building a new access infrastructure to support this range of services is expensive. For these situations, leveraging the existing network with new multi-service access platforms can maximize value. These multi-service access solutions provide the flexibility to support a broad range of applications and services, including narrowband voice, broadband DSL and TDM special services.

A multi-service access platform is a scalable, integrated system that can provide a wide range of voice and data services from a single chassis. It comprises the following main components:

- TDM-based subsystem
- ATM-based subsystem
- IP/Ethernet-based subsystem
- Set of line cards that support both voice and data services

A good example of a multi-service access platform is the Lucent Technologies AnyMedia Access System. It is one of the industry's highest density multi-service access platforms supporting both new growth and Central Office consolidation applications.
With a unified voice/data element management system, the AnyMedia Access System can minimize service creation and delivery costs with decreased complexity

Electrical Systems

Standards Organizations

ANSI – American National Standards Institute
www.ansi.org

ANSI facilitates the development of Standards by accrediting the procedures of those agencies that develop standards.

NECA – National Electrical Constructors Association
www.necanet.org

NECA installation standards are recommended practices intended to establish a baseline level of quality for electrical construction. They are intended to define what is meant by a "neat and workmanlike installation". NECA installation standards are not mandatory electrical safety rules. NECA installation standards are intended to provide advice and guidance only.

NECA 1-2000, Standard Practices for Good Workmanship in Electrical Contracting (ANSI)

NECA 1 defines "neat and workmanlike" procedures for installing a variety of electrical equipment. As the centerpiece publication of the series, it covers a variety of topics that include handling construction materials on site, installing, mounting, and supporting electrical equipment, and the Americans with Disability Act Guidelines for locating electrical products and systems. NECA 1 is approved as an American National Standard (ANSI).

NECA 1000-NEIS Specification System

The complete set of current ANSI-approved installation standards, including: NECA 1, Good Workmanship; NECA 100, Electrical Symbols; NECA 101, Steel Conduits; NECA 104, Aluminum Wire and Cable; NECA 105, Metal Cable Tray Systems; NECA 111, Nonmetallic Raceways; NECA 200, Temporary Electric Power; NECA 202, Industrial Heat Tracing; NECA 230, Motors; NECA 301, Fiber Optic Cables; NECA 305, Fire Alarm Systems; NECA 400, Switchboards; NECA 402, Motor Control Centers; NECA 404, Generator Sets; NECA 405, Interconnected Generation Systems; NECA 406, Residential Generators; NECA 407, Panelboards; NECA 408, Busways; NECA 409, Dry-Type Transformers; NECA 500, Indoor Commercial Lighting; NECA 501, Exterior Lighting; NECA 502, Industrial Lighting; and NECA 568, Telecommunications; NECA 600, Medium-Voltage Cable.

NECA 200, Recommended Practice for Installing and Maintaining Temporary Electric Power at Construction Sites (ANSI)

This publication describes installation procedures for temporary power at construction sites. It covers the planning, installation, expansion, maintenance, cutover, and removal of temporary power systems operating at 600 volts or less. NECA 200 is approved as an American National Standard (ANSI).

NECA 305-2001, Standard for Fire Alarm System Job Practices (ANSI)

Describes fire alarm system job practices for installing, testing, and maintaining fire alarm systems. These job practices represent a minimum level of quality for fire alarm system installations. NECA 305 is approved as an American National Standard (ANSI).

NECA 406-2003, Recommended Practice for Installing Residential Generator Sets (ANSI)

Describes installation procedures for (a) Generator sets permanently installed at one-family dwellings to provide backup power, typically rated 120/240 volts, single-phase, three-wire; and (b) Generator sets fueled by gasoline, natural gas, or liquefied petroleum (LP) gas. NECA 406 is approved as an American National Standard (ANSI).

NECA/AA 104-2000, Recommended Practice for Installing Aluminum Building Wire and Cable (ANSI)

Describes installation procedures and design considerations for aluminum building wire and cable in residential, commercial, institutional, and industrial applications not exceeding 600 volts. Developed jointly with The Aluminum Association, NECA/AA 104 is approved as an American National Standard (ANSI).

NECA 111-2003, Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC) (ANSI)

Describes installation procedures for nonmetallic raceways of circular cross-section used for electrical power wire and cable, communications wiring, or fiber optic cables. NECA 111 is approved as an American National Standard (ANSI).

NEMA – National Electrical Manufactures Association
www.nema.org

NEMA is responsible for establishing standards for connectors for electrical utility transmission, overhead and underground distributions and substations.

DC 12-1985 (R1991, R1996, R2002)
Residential Controls: Hot Water Immersion Controls

Defines basic construction standards and performance characteristics of electric switch type hot water immersion controls intended primarily for use with hot water boilers and heaters used in residential heating.

Residential Controls--Electrical Wall-Mounted Room Thermostats

Covers self-contained, electrical and electronic, wall-mounted room thermostats for controlling the temperature of the space in which the thermostat is mounted by controlling the applied energy for heating, cooling, or heating-cooling.

Residential Controls--Surface-Type Controls for Electric Storage Water Heaters

Provides construction and mounting considerations for surface type control thermostats and temperature limiting controls for electric storage water heaters.

LSD 8-1999
Compact Fluorescent Lamps In Residences – Power Quality Implications

There continues to be a growing proliferation of high reliability, low cost electronic products that can represent non-linear loads from a power systems point of view. These products include entertainment devices such as TV's, VCR's, and audio equipment; information technology devices such as PC's, printers, and fax machines; variable speed motor drives for HVAC, and white goods appliances; food preparation and cooking products such as microwaves and cooktops; and lighting products, which include electronic ballasts, compact screw-in fluorescent lamps (CFLs), and other power conversion devices that operate a variety of lamps. The proliferation of such products results in an increased growth of so-called non-linear loads from a utility point of view. Products with non-linear loads are not new- but it can be argued that we have entered a period where the growth will be unprecedented in all major end-use segments: residential, commercial, and industrial. This growth has led to an increasing concern by some utilities on the effects from such loads on power quality.

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NEMA PB 1-2000 - Panelboards

Covers single panelboards or groups of panel units suitable for assembly in the form of single panelboards, including buses, with or without switches or automatic overload protective devices (fuses or circuit breakers), or both. These units are used in the distribution of electricity for light, heat, and power at 600 volts and less, with 1600 ampere mains and less and 1200 ampere branch circuits and less. Excluded are live front panelboards, panelboards using cast enclosures for special service conditions, and panelboards designed primarily for residential and light commercial service equipment.

IEEE – Institute of Electrical and Electronics Engineering
www.ieee.org/portal/site

IEEE activities are within the technological field of advancement of the theory and practice of electrical engineering, electronics, radio and the allied branches of engineering, and the related arts and sciences. Standards relate to the following activities: definitions of terminology, methods of measurement and tests, rating structures, temperature limits, application guides, recommended practices, and safety.

ANSI/IEEE Std 929-1988 IEEE recommended practice for utility interface of residential and intermediate photovoltaic (PV) systems

IEEE Std 1216-2000 IEEE guide for the application of faulted circuit indicators for 200 A, single-phase underground residential distribution

EEE P1547, Standard for Distributed Resources Interconnected with Electric Power Systems.

ASME – American Society of Mechanical Engineers
www.asme.org

PTC 50 Performance Test Code—Fuel Cell Power Systems Performance

UL – Underwriters Laboratory
www.ul.com

UL Laboratory issues standards for a number of products used in electrical construction to ensure safety of the products.

Electrical Codes

NEC – National Fire Protection Association - National Electrical Code

The NEC covers the installation of electric conductors and equipment in public and private buildings or other structures (including mobile homes, recreational vehicles, and floating buildings), industrial substations, and other premises (such as yards, carnivals, and parking lots). Wiring, general electrical equipment, the use of electricity in specific occupancies (from aircraft hangars to health care facilities), and equipment (ranging from elevators to hot tubs) are covered, as well as special conditions (emergency and stand-by power, or conditions requiring more than 600 volts, for example) and communication systems.

Electrical Systems and Materials

Oyarzabal, B., Spankovsky, M. & Ellis, M. (2004). *Optimal Synthesis/Design of a Pem Fuel Cell Cogeneration System for Multi-Unit Residential Applications – Application of a Decomposition Strategy*. Journal of Energy Resources Technology v. 126 (1).

The application of a decomposition methodology to the synthesis/design optimization of a stationary cogeneration proton exchange membrane (PEM) fuel cell system for residential applications is the focus of this paper. Detailed thermodynamic, economic, and geometric models were developed to describe the operation and cost of the fuel processing sub-system and the fuel cell stack sub-system. Details of these models are given in an accompanying paper by the authors. In the present paper, the case is made for the

usefulness and need of decomposition in large-scale optimization. The types of decomposition strategies considered are conceptual, time, and physical decomposition. Specific solution approaches to the latter, namely Local-Global Optimization (LGO) are outlined in the paper. Conceptual/time decomposition and physical decomposition using the LGO approach are applied to the fuel cell system. These techniques prove to be useful tools for simplifying the overall synthesis/design optimization problem of the fuel cell system. The results of the decomposed synthesis/design optimization indicate that this system is more economical for a relatively large cluster of residences (i.e. 50). Results also show that a unit cost of power production of less than 10 cents/kWh on an energy basis requires the manufacture of more than 1500 fuel cell sub-system units per year. Finally, based on the off-design optimization results, the fuel cell system is unable by itself to satisfy the winter heat demands. Thus, the case is made for integrating the fuel cell system with another system, namely, a heat pump, to form what is called a total energy system.

Aronstien, J. (1998). *Environmental Conditions of Residential Electrical Connections*. Proceedings of the Annual Holm Conference on Electrical Contacts, Oct. 26-28, Arlington, VA.

The temperature and humidity inside various electrical enclosures in residential structures was measured. Conditions within the enclosures are seen to be harsh relative to the indoor ambient that is used for standard qualification tests. There are large temperature excursions and sustained periods of high humidity. Based on the long-term data, a method is presented for estimating the temperature and humidity extremes that are encountered by connections in a high representative cross section of residential wiring system applications.

Braun, R. (2004). *Considerations in the design and application of solid oxide fuel cell energy systems in residential markets*. ASHRAE Transactions, v. 110 (1).

This paper examines aspects of fuel cell system design for application in stationary residential markets. The development of fuel cell systems for sub- 10 kW stationary applications involves consideration of sizing, fuel processing, operating point selection, fuel cell operating capabilities, system integration, and load management strategies. Each of these considerations are discussed, and strategies are presented for matching the electrical and thermal energy demands of a residence with a solid oxide fuel cell power system. Efficiency considerations for configuring fuel cell, DC to AC inverter, and electrical energy storage components for conditioning of DC power generated by the fuel cell stack are also given.

Priedeman, D., Garrabrant, M., Mathias, J., Stout, R., and Christensen, R. (2000). *Performance of a Residential-Sized GAX Absorption Chiller*. Journal of Energy Resources Technology v. 123 (3).

This research effort involved experimentally testing an advanced-cycle, ammonia-water absorption chiller with a cooling capacity of 17.6 kW (5 refrigeration tons (RT)). The system was a generator-absorber heat exchange (GAX) cycle and was sized for residential and light commercial use, where very little absorption equipment is currently used. The components of the cycle were assembled with instrumentation, including flow meters, pressure transducers, and thermocouples. The findings of the research were cycle cooling load and coefficient of performance (COP), as well as many component heat duties and working fluid state points throughout the cycle. The COP of the chiller at essentially full load was measured at 0.68. A simulation of the GAX cycle was performed with a computer program that predicted the heat duties of each component and the cooling load of the cycle. The simulation of the GAX cycle and experimental testing compared closely. Existing market research shows that significant business opportunities exist for a GAX heat pump or chiller with a cooling COP of 0.70 or greater.

www.toolbase.org. *Institutional Factors Affecting Commercialization of Fuel Cells. Path Technology Inventory*. Online [May 22, 2004].

Distributed generation (DG) involves the placement and use of small, modular electric generation, either integrated or stand-alone, close to the point of consumption. Fuel cells are poised to become an important component of DG in stationary applications involving commercial and residential buildings. Still under development and in the initial stages of commercialization, fuel cell technology competes with other DG technologies. These technologies include conventional small gas turbines and internal combustion engines, renewable energy generators such as photovoltaics (PV) and wind, as well as emerging microturbine technology. This report seeks to gain an understanding of the institutional and policy issues that provide barriers or opportunities for the commercialization of DG in general and fuel cells in particular in buildings. An initial review of the economics and regulatory evolution of stationary generation of electric power in the United States explains the origin of some of the barriers and opportunities that confront the commercialization of DG.

www.toolbase.org. *Technical Factors Affecting the Commercialization of Fuel Cells*. Path Technology Inventory. Online [May 22, 2004].

The purpose of this report is to identify the technical and building code issues and electric system interconnection choices related to the use of fuel cells in residential buildings. This technical assessment, as a basis for a full residential field evaluation of fuel cell technology, provides background information in the areas of:

- Building codes and standards,
- Home utility supply connections, and
- Options for connection of primary or ancillary electrical supply sources to residential buildings

Lee, D., Trotta, A., & King, W. (2000). *New Technology for Preventing Residential Electrical Fires: Arc-Fault Circuit Interrupters*. Fire Technology, v. 36 (3).

A new generation of residential electrical branch circuit breakers that incorporates technology to detect and mitigate the effects of arcing faults is described. Fire loss estimates attributed to electrical wiring and the development of the arc-fault circuit interrupter for the prevention of residential electrical fires are discussed. The industry voluntary standards for arc-fault circuit interrupters as well as the 1999 National Electrical Code requirement are reviewed.

www.toolbase.org. (2004). *Final Report for Field Evaluation of PATH Technologies Shea Homes, San Diego, California*. PATH Field Evaluations.

This field evaluation demonstrated that reducing utility energy usage can be accomplished just as effectively through energy conservation as through on-site energy generation. Of the five homes studied in this evaluation, a Base Home actually used the least amount of utility electricity. The homeowner was able to reduce electricity use through replacing many of his incandescent lights with compact fluorescent light bulbs that consume about ¼ the energy.

Gunes, B. (2001). *Evaluation of fuel cell based combined heat and power systems for residential applications.* American Society of Mechanical Engineers Advanced Energy Systems. v. 41.

The advent of fuel cell power systems makes on-site power generation feasible for residential applications. With on-site generation, waste heat can be recovered and used to meet the thermal needs of the residence including space heating and water heating. Combined heat and power (CHP) systems can substantially reduce the energy required for residential applications. The energy use and economic benefits of fuel cell based CHP systems are investigated for single-family residential applications. Hourly energy use profiles for electricity and thermal energy are determined for typical residential applications. A mathematical model of a residential fuel cell based CHP system is developed. The system incorporates a fuel cell system to supply electricity and thermal energy, a vapor compression heat pump to provide cooling in the summer and heating in the winter, and a thermal storage tank to help match the available thermal energy to the thermal energy needs. The performance of the system is evaluated for different climates. Results from the study include an evaluation of the major design characteristics of the system, load duration curves, an evaluation of the effect of climate on energy use characteristics, and a comparison of the life cycle cost of the fuel cell based CHP system to the life cycle costs of conventional residential energy systems.

Hongo, I. &Saito, K. (1993). *Development of small twin-valveless pulse combustors: Effect of Injection Systems*. Combustion Science and Technology, v. 94 (1).

The performance of gas-fired residential sized twin pulse combustors with two aerodynamic valves for residential heating appliances is discussed. Two injection systems are tested. Pre-mixed injection resulted in having better stability of anti-phase operating mode between the two combustion chambers which reduced the noise level less than 50 dB(A). The combustor shows NO_x emissions of 25 ppm and a thermal efficiency of 93% over a wide turndown from 1,100 to 6,000 W. At a lower heat input region, the combustor can still operate in the anti-phase mode with fuel supply to only one combustor. It is shown that twin-valveless pulse combustors have the potential for compactness, low noise, and efficient operation over a wide turn down ratio for residential use.

Smith, R., Hwang, C & Dougall, R. (1993). *Modeling of a solar-assisted desiccant air conditioner for a residential building.* American Society of Mechanical Engineers, Advanced Energy Systems, v 30.

The objective of this work was to develop a mathematical model of a solar-assisted desiccant air conditioner and simulate its performance in a residential building. The desiccant air conditioner modeled operates on the Munters Environmental Control (MEC) cycle. Based on the air conditioner model developed, a cooling system was designed in accordance with accepted HVAC engineering practice. The performance of this cooling system was evaluated in a residential building at various locations by means of computer simulations. Results obtained indicate that desiccant air conditioning can meet the cooling loads present in the three locations evaluated. The air conditioner design itself exhibits better than expected performance in all three locations considered. Desiccant cooling appears to be well matched to the available solar resource in the southwestern United States. However, it appears that a significant amount of auxiliary energy is required to power the system in the northeastern and in particular, the southeastern United States. It is recommended that alternative thermal energy sources be evaluated for use with desiccant air conditioning in these locations.

Bakos, G., Souros, M. & Tsagas, N. (2003). *Technoeconomic assessment of a building-integrated PV system for electrical energy saving in residential sector*. Energy and Buildings, v. 35 (8).

This paper describes the installation, technical characteristics, operation and economic evaluation of a grid-connected building-integrated photovoltaic system (BIPV) installed in Northern Greece, and in particular in the city of Kastoria. The technical and economical factors are examined using a computerized renewable energy technologies (RETs) assessment tool. A number of different economic and financial feasibility indices are calculated for different financing scenarios in order to assess the gross return of the investment. Useful conclusions were drawn regarding the feasibility of BIPV systems and their potential for increased energy market penetration.

Bazilian, M. & Prasad, D. (2002). *Modeling of a photovoltaic heat recovery system and its role in a design decision support tool for building professionals*. Renewable Energy, v. 27 (1).

A numerical model has been created to simulate the performance of a residential-scale building integrated photovoltaic (BiPV) cogeneration system. The investigation examines the combined heat and power system in the context of heat transfer. The PV cogeneration system will be based on existing BiPV roofing technology with the addition of a modular heat recovery unit that can be used in new or renovation construction schemes. The convection of the air behind the panels will serve to cool the PV panels while providing a heat source for the residence. This model was created in the Engineering Equation Solver software package (EES), from a series of highly coupled non-linear partial differential equations that are solved iteratively. The model's ability to utilize climatic data to simulate annual performance of the system will be presented along with a comparison to

experimental data. A graphical front-end has been added to the model in order to facilitate its use as a predictive tool for building professionals. It will thus become a decision support tool used in identifying areas for implementation of a PV cogen system

Ingersoll, J. & Huang, J. (1985). *Heating energy use management in residential buildings by temperature control.* Energy and Buildings, v. 8 (1).

This paper presents the results of analytical investigations to determine the potential heating energy savings that can be achieved in residential buildings by controlling the house temperature through either night setback or night setback plus day zone setback. A typical U.S. single family house is analyzed for different levels of thermal integrity of the building envelope (i.e., levels of insulation, window glazing, and infiltration). Reduced infiltration, insulated interior walls, and various window orientations are also considered. Results are given for four major U.S. climate zones—cool, temperate, hot-humid, and hot-arid. The analysis shows that both types of setbacks are most effective in loose houses, with the greatest absolute savings for the cool climates, and the greatest percent savings for the hot climates. However, the benefits from thermostat setbacks are smaller for tighter houses, and may actually be counterproductive owing to corollary effects such as increased peak loads and degradation of system efficiency.

Wells, J. (2004). *Low Cost Single-Phased Powered Induction Machine Drive for Residential Applications.* IEEE Applied Power Electronics Conference and Exposition, v. 3.

This article discusses a low cost integrated machine and drive system for residential applications between 50 and 500 W. The objective is to remain cost competitive with traditional single phase induction machine solutions while improving system performance. The basic architecture includes a power factor correction boost rectifier, a hex-bridge inverter, control circuitry implementing selective harmonic elimination, auxiliary power supplies, and a three phase induction machine designed for inverter operation. This paper discusses system design, performance, cost, and lifetime.

Plumbing

Standards Organizations

ANSI – American National Standards Institute
www.ansi.org

ANSI facilitates the development of Standards by accrediting the procedures of those agencies that develop standards.

The following agencies are ANSI certified to perform third party inspections for plumbing products:

CSA International – Plumbing Products

ICC Evaluation Services – Plumbing Fixtures and Systems
IAPMO – Other Plumbing Products, Manufactured Housing Plumbing Products
Intertek Testing Services, NA Inc. – Plumbing Products
NSF International – Plastic and Plumbing Systems and Components
Truesdail Laboratories – Plumbing Products
Underwriters Laboratories – Plumbing, Sewer Handling, and Piping Products

ASSE – American Society of Sanitary Engineers
www.asse-plumbing.org

ASSE Standard # 1001- 2002
Performance Requirements for Atmospheric Type Vacuum Breakers

ANSI Approved 2002
This standard applies to devices classified as atmospheric type vacuum breakers that are single pipe-applied (does not apply to tank ball cocks or similar devices that depend on float operated valves to control flow). The purpose of these devices is to provide protection of the potable water supply against pollutants or contaminants that enter the system due to backsiphonage through the outlet. Under backsiphonage conditions, a small amount of water is permitted to exit through the air ports.

ASSE Standard #1002-1999
Performance Requirements for Anti-Siphon Fill Valves (Ballcocks) for Gravity Water Closet Flush Tanks

This standard provides dimensional and minimum performance requirements for anti-siphon fill valves (ballcocks) for gravity water closet flush tanks including protection of the potable water supply against back siphonage of water from the flush tank.

ASSE Standard #1003-2001
Performance Requirements for Water Pressure Reducing Valves

ANSI Approved - 2001

Devices covered by this standard are self-contained, direct acting, single diaphragm types. Devices shall be permitted to have an integral strainer, separate strainer connected to the valve inlet, or be without strainer. Devices shall be permitted to be with or without an integral bypass relief valve. The purpose of this device is to reduce static and flowing pressures in water distribution systems.

ASSE Standard #1004-1990
Performance Requirements for Backflow Prevention Requirements for Commercial Dishwashing Machines

This standard covers the requirements for the protection of the potable water supply from pollution as a part of and within a commercial dishwashing machine and the means of discharging waste.

ASSE Standard #1005-1999
Performance Requirements for Water Heater Drain Valves

This standard covers those water heater drain valves, $^{3}/_{4}$ pipe size used as a component of water heaters for the purpose of drawing water from or draining a water heater.

ASSE Standard #1006-1986
Performance Requirements for Residential Use Dishwashers

This standard applies to residential use (household) type dishwashers, both front loading and top loading, requiring connection to the potable water supply and discharging into the plumbing drainage system.

ASSE Standard #1007-1986
Performance Requirements for Home Laundry Equipment

This standard applies to household type automatic and semiautomatic clothes washers, combination washer-dryers, and dryers including those household types that are coin-operated, requiring connection to the potable water supply and discharging into the building plumbing drainage system.

ASSE Standard #1008-1986
Performance Requirements for Household Food Waste Disposer Units

This standard applies to household type food waste disposers intended for installation in the household kitchen sink outlet, supplied with water from the sink supply faucet and discharged into the household plumbing drainage system. This standard does not apply to commercial food waste disposers intended for installation in a food handling establishment.

ASSE Standard #1009-1990
Performance Requirements for Commercial Food Waste Grinder Units

This standard applies to food waste grinders designed and intended for use in food establishments, supplied with water and which discharges waste into a plumbing drainage system.

ASSE Standard #1010-2004
Performance Requirements for Water Hammer Arresters

ANSI Approved - 2004

This standard applies only to those devices classified as water hammer arresters having a permanently sealed cushion of water or gas isolated from the waterway, and designed to provide continuous protection, without maintenance, against detrimental surge pressures within the water distribution system. Water hammer arresters are installed on water distribution system piping to prevent over pressures within water distribution systems, thereby prolonging the service life of valves, piping, fittings, trim, equipment, appliances, appurtenances, and other devices which are part of the distribution system; and to eliminate noise.

ASSE Standard #1011-2004
Performance Requirements for Hose Connection Vacuum Breakers

ANSI Approved - 2004

This standard applies only to those devices classified as Vacuum Breakers, Hose Connection Type, which are designed to be installed on the discharge side of the hose bibb, hydrant or faucet which is fitted with hose threads. The design embraces a check valve member force loaded, or biased, to a closed position, and an atmospheric vent valve, force loaded, or biased, to an open position when the device is not under pressure. This device shall not be subjected to continuous pressure. Continuous pressure shall mean twelve (12) hours use in a twenty-four (24) hour period. Mechanical means used to defeat the vacuum breaker shall not be used. This device shall only be used on systems where the only source of low head back pressure comes from an elevated hose equal to or less than three (3.0) meters (10 feet) in height.

ASSE Standard #1012-2002
Performance Requirements for Backflow Preventer with Intermediate Atmospheric Vent

ANSI Approved - 2002

The devices covered by this standard are those, which have functional capabilities for preventing both backsiphonage and backpressure backflow in the potable water supply lines, and which can operate under continuous or intermittent pressure conditions. These devices have two independently operating check valves separated by an intermediate chamber with a means for automatically venting it to the atmosphere. The check valves are force loaded to a normally closed position and the venting means is force loaded to a normally open position.

ASSE Standard #1013-1999
Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers

ANSI Approved – 1999

This standard applies only to two types of backflow prevention assemblies identified as (RP) “Reduced Pressure Principle Backflow Preventers” and (RPF) “Reduced Pressure Principle Fire Protection Backflow Preventers.” These assemblies consist of two (2) independently-acting check valves, internally force loaded to a normally closed position, and separated by an intermediate chamber (or zone) in which there is an hydraulically operated relief means for venting to atmosphere, internally force loaded to a normally open position. These assemblies are designed to operate under continuous pressure conditions. The assembly shall include two (2) tightly closing shut-off valves, and contain properly located test cocks. This standard also applies to Manifold Reduced Pressure Principle Backflow Assemblies. They consist of two or more complete Reduced Pressure Principle Backflow Preventers in parallel. The assemblies do not need to be of the same pipe size. The manifold size shall be identified by the single inlet and outlet of the manifold reduced pressure principal backflow assembly. It shall consist of shut-off valves on the inlet and outlet of each of the assemblies in the manifold and the shut-off valves shall be line sized to each backflow assembly in the manifold

ASSE Standard #1014-1989
Performance Requirements for Hand-Held Showers

This standard covers only products which consist of a hose and a hand held discharge piece (shower head, spray, etc.). These products include a backflow preventer.

ASSE Standard #1015-1999
Performance Requirements for Double Check Backflow Prevention Assemblies and Double Check Fire Protection Backflow Prevention Assemblies

ANSI Approved - 1999

This standard applies to two types of backflow prevention assemblies identified as a (DC) Double Check Backflow Prevention Assembly and (DCF) Double Check Fire Protection Backflow Prevention Assembly. These devices consists of two (2) independently acting check valves, internally force loaded to a normally closed position, two (2) tightly closing shut-off (isolation) valves, and properly located test cocks. This device is designed and constructed to operate under intermittent or continuous pressure conditions. This standard also applies to Manifold Double Check Backflow Prevention Assemblies. They consist of two or more complete Double Check Backflow Prevention Assemblies in parallel. The devices do not need to be of the same pipe size. The manifold size shall be identified by the single inlet and outlet of the manifold device. It shall consist of shut-off valves on the inlet and outlet of each of the devices in the manifold and the shut-off valves shall be line sized to each backflow device in the manifold.

ASSE Standard #1016-1996
Performance Requirements for Individual Thermostatic, Pressure Balancing, and Combination Pressure Balancing and Thermostatic Control Valves for Individual Fixture Fittings

The three types of individual control valves covered by this standard are: (1) Pressure balancing valve (Type P) senses incoming hot and cold water pressures and compensates for fluctuations in either to stabilize outlet temperature; (2) Thermostatic valves (Type T) senses outlet temperature and compensates for fluctuations in either incoming hot and cold water temperature and/or pressure; and (3) Combination thermostatic/pressure balancing valve (Type T/P) senses outlet temperature and incoming hot and cold water pressures and compensates for fluctuation in incoming hot and cold water temperatures or pressures to stabilize outlet temperature.

ASSE Standard #1017-2003
Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems

Temperature Actuated Mixing Valves for Hot Water Distribution Systems are used for controlling in-line water temperatures in domestic potable hot water systems. They are not intended for end use application.

ASSE Standard #1018-2001
Performance Requirements for Trap Seal Primer Valves - Potable Water Supplied

ANSI Approved – 2002

Devices covered by this standard are designed primarily to supply water to drain traps which have infrequent use and in which water evaporation would allow sewer gas to enter the premises. This type of device is located in the domestic water distribution system and is designed to supply potable water to a drain trap to maintain the water seal. A means for the prevention of backsiphonage shall be incorporated as part of the device.

ASSE Standard #1020-2004
Performance Requirements for Pressure Vacuum Breaker Assembly

ANSI Approved - 2004

Pressure vacuum breaker assemblies are for installation in water supply lines to prevent the entrance of non-potable material into the potable water supply by backsiphonage only. It is not for use in any system where backpressure can be applied to the assembly.

ASSE Standard #1021-2001
Performance Requirements for Drain Air Gaps for Domestic Dishwasher Applications

ANSI Approval Pending

Products covered by the standard are devices for installation in the drain line of residential dishwashers. The purpose of this device is to prevent the backflow of contaminated liquid and entrained material into the dishwasher.

ASSE Standard #1023-1979
Performance Requirements for Hot Water Dispensers Household Storage Type - Electrical

The hot water dispensers covered by this standard are those which are designed for household use and which are installed at the sink and supplied with water from the kitchen sink water supply. They are storage types, continuously vented to atmosphere and heated electrically.

ASSE Standard #1024-2004
Performance Requirements for Dual Check Backflow Preventers

ANSI Approved – 2004

This standard applies only to the type of backflow preventer identified as a dual check backflow preventer. This device consists of two (2) independently acting check valves, internally force loaded to a normally closed position, designed and constructed to operate under intermittent or continuous pressure conditions. The purpose of the dual check backflow preventer is to keep polluted water from flowing back into the potable water system, when pressure is temporarily higher in the polluted part of the system than in the potable water piping. The devices covered by this standard are intended to protect the potable water supply from low hazard pollution at residential service lines and individual outlets. These devices are intended for cold water service under continuous or intermittent pressure conditions. Usage with hot water is limited to the temperature specified by the manufacturer.

ASSE Standard #1025-1978
Performance Requirements for Diverters for Plumbing Faucets with Hose Spray, Anti-Siphon Type, Residential Applications

Covers complete and independent components of plumbing faucets intended for use in sink type plumbing fixtures to which is connected a flexible hose and spray assembly.

ASSE Standard #1037-1990
Performance Requirements for Pressurized Flushing Devices (Flushometers) for Plumbing Fixtures

This standard establishes basic performance requirements for pressurized flushing devices, for the safe and sanitary operation of plumbing fixtures.

ASSE Standard #1043-1992
Performance Requirements for Cast Iron Sovent Sanitary Drainage Systems

This standard establishes functional performance requirements for cast iron sovent drainage fittings, aerators and deaerators, and installation guidelines for the system. A cast iron sovent system is a single-stack drainage, waste and vent system that uses special fittings (aerators and deaerators) to maintain the differential pressures within the system near atmosphere, thereby protecting the trap seals of the connected fixtures.

ASSE Standard #1044-2001
Performance Requirements for Trap Seal Primer Devices - Drainage Types and Electronic Design Types

ANSI Approved - 2002

Devices covered by this performance standard are designed primarily to supply water to floor drain traps which have infrequent use and in which water evaporation would allow sewer gas to enter the premises. The type of device covered by this standard is designed to supply water to a drain trap to provide and maintain its water seal using a supply from a fixture drainline, ballcock, or flushometer valve tailpiece or an electronic primer device. The rate of water flow to the trap shall be permitted to be fixed or adjustable. The devices are of four (4) types: (a) Those which are installed on waste line tail pieces from fixtures, such as lavatories, sinks and similar fixtures where grease is not normally generated; (b) Those which are used in conjunction with ballcock assemblies; (c) Those which receive flow from flushometer valves; and (d) Those electronics devices which discharge water automatically and which are upstream of the air gap or vacuum breaker.

ASSE Standard #1050-2002
Performance Requirements for Stack Air Admittance Valves for Sanitary Drainage Systems

ANSI Approval Pending
Stack Air Admittance Valves for Sanitary Drainage Systems (herein referred to as "device") are devices used as vent terminals for stacks in plumbing drainage systems. These devices shall not be used to relieve back pressure, but only to allow air to enter the system. When these devices are installed in a building, there shall be at least one (1) open vent terminal which extends to atmosphere outside of the building serving the building drain on which these devices are installed. These devices are designed to be installed on stacks where branches on multiple floors are connected. These devices consist of a one-way valve designed to allow air to enter the plumbing drainage system when a pressure less than atmospheric develops. The device closes and seals by gravity under zero (0) differential pressure (static or no flow condition) and under positive pressure. These devices prevent sewer gases from entering a building. The device consists of a hooded or shielded body which contains a movable guided diaphragm which seats and seals air flow when closed and allows air to enter when open.

ASSE Standard #1051-2002
Performance Requirements for Individual and Branch Type Air Admittance Valves for Sanitary Drainage Systems

ANSI Approval Pending
Individual and Branch Type Air Admittance Valves for Sanitary Drainage Systems (AAV's) (herein referred to as "device") are devices used as vent terminals for individual and branch fixtures in plumbing drainage systems. These devices shall not be used to relieve back pressure, but only to allow air to enter the system. When the devices are installed in a building, there shall be at least one (1) open vent terminal which extends to atmosphere outside of the building serving the same building drain on which these devices are installed. These devices are designed to be used for individual fixtures or for a branch serving multiple fixtures. These devices consist of a one-way valve designed to allow air to enter the plumbing drainage system when a pressure less than atmospheric develops. The device closes and seals by gravity under positive pressure. These devices prevent sewer gases from entering the building. The device consists of a hooded or shielded body which contains a movable guided diaphragm which seats and seals air flow when closed and allows air to enter when open.

ASSE Standard #1052-2004
Performance Requirements for Hose Connection Backflow Preventers

ANSI Approved - 2004

This standard establishes physical requirements, basic performance requirements and test procedures for hose connection backflow preventers. This device is designed to be installed on the discharge side of a hose threaded outlet on a potable water system. This two-check device protects against backflow, due to backsiphonage and low-head backpressure, under the high hazard conditions present at a hose threaded outlet. This device shall only be used on systems where sources of backpressure are not introduced. This device shall only be used on systems where the low-head backpressure does not exceed that generated by an elevated hose equal to or less than 3 m (10 ft.) in height. This device shall not be subjected to more than twelve (12) hours of continuous water pressure. A hose connection backflow preventer shall consist of two independent checks, force loaded or biased to a closed position, with an atmospheric vent located between the two check valves, which is force loaded or biased to an open position, and a means for attaching a hose.

ASSE Standard #1056-2001
Performance Requirements for Spill Resistant Vacuum Breaker

ANSI Approved - 2002

Spill Resistant Vacuum Breakers (herein referred to as "device") are installed in the potable water supply lines to prevent the backflow or nonpotable material into the potable water supply caused by backsiphonage only. They are not for use in any system where back pressure is applied to the device. When the system is pressurized, the vent closes to prevent a flow through the upstream check valve, and to eliminate vent spillage. This standard applies only to those devices classified as Spill Resistant Vacuum Breakers - SVB. These devices are designed for installation in those portions of the domestic potable water systems that are normally under continuous pressure conditions. The device includes one (1) check valve force-loaded closed and an air inlet vent valve force loaded open to atmosphere, positioned downstream of the check valve, and located between and including two (2) tightly closing shut-off valves and two (2) test cocks.

ASSE Standard #1060-1996
Performance Requirements for Outdoor Enclosures for Backflow Prevention Assemblies

This standard details the requirements of an outside enclosure for various types of backflow prevention assemblies. It includes enclosure types for freezing and non-freezing locations. The enclosures incorporate features to provide for freeze protection, positive drainage to prevent submergence of the assembly, security and accessibility for testing and repair.

ASSE Standard #1062-1997
Performance Requirements for Temperature Actuated Flow Reduction (TAFR) Valves for Individual Fixture Fittings

This standard applies to Temperature Actuated, Flow Reduction (TAFR) Valves for Individual Fixtures Fittings which react to high temperature water. These valves reduce flow to 0.95 L/min (0.25 GPM) or less automatically in response to outlet temperatures greater than a preset actuation temperature not to exceed 49 °C (120 °F) so as to limit exposure to high temperature water discharge from an individual fixture fitting. TAFR valves covered by this standard are intended for use in-line with or are integrated into individual plumbing fixtures fittings, such as shower heads; bath and utility faucets; and sink and lavatory faucets. TAFR with disabilities shall also comply with ANSI/CABO Standard A117.1. Devices covered by this standard shall be mechanically or electrically operated, shall be installed in-line with or integrated into fixture fittings; and after actuation, shall reset open automatically or use a manual reset mechanism.

ASSE Standard #1064-2001
Performance Requirements for Backflow Prevention Assembly Field Test Kits

ANSI Approved - 2002

Portable backflow prevention assembly field test kits (herein referred to as "BFTK") shall be used in testing the performance of backflow prevention assemblies. This standard covers the performance requirements, and accuracy of a BFTK. This standard is confined to analog dial type and digital instrumentation. Duplex gauges are not a part of this standard. They shall be designed to indicate the operation of a backflow prevention assembly to pre-established testing procedures. The backflow field test kit shall include all gauges, hoses, valves and fittings as required for testing purposes.

ASSE Standard #1066-1997
Performance Requirements for Individual Pressure Balancing In-Line Valves for Individual Fixture Fittings

This standard applies to automatic pressure balancing in-line valves which are used to equalize incoming hot and cold water line pressures for the purpose of minimizing mixed water temperature variations due to pressure fluctuations when used in conjunction with a mixing valve or two handle valve set. They are not designed to limit the maximum outlet temperature at the point-of-use. These devices are intended for use in individual plumbing fixture~~s~~ fittings such as shower heads, bath utility faucets, and sink and lavatory faucets.

ASSE Standard #1070-2004
Performance Requirements for Water Temperature Limiting Devices

ANSI Approved - 2004

Water Temperature Limiting Devices shall control and limit the water temperature to fittings for fixtures such as sinks, lavatories or bathtubs and are intended to reduce the risk of scalding. These devices are intended to supply tempered water to plumbing fixture fittings, or be integral with plumbing fixture fittings supplying tempered water. The device shall be equipped with an adjustable and lockable means to limit the setting of the device towards the hot position. Where the device is integral to the fixture fitting, it shall comply with the requirements of ASME A112.18.1.

AWWA – American Water Works Association
www.awwa.org

Topics include water sources, water treatment, pipe and accessories, disinfection, meters, and more.

NSF – National Sanitary Foundation
www.nsf.org

NSF assesses and certifies plumbing products as follows:

Plastic Plumbing Products

NSF International developed Standard 14 - Plastics Piping System Components and Related Materials in October, 1965. NSF Standard14 establishes minimum physical, performance, health effects, quality assurance, marking, and record keeping requirements for plastic piping components and related materials.

Mechanical Plumbing Products

The Mechanical Plumbing Program works with voluntary standard NSF/ANSI Standards 24 and 61 that represent consensus of manufacturers, users, and regulatory people. NSF offers a conformity assessment program which includes performance and health effects testing, certification, and production facility inspections -- to verify compliance.

Faucets

The 1996 amendments to the U.S. Safe Drinking Water Act (SDWA) require that pipe, fittings, and fixtures introduced into commerce after August 6, 1998, be lead-free. For pipe, fittings, and devices, this requires that the products not contain more than 8.0% lead.

In addition, for devices that are intended by the manufacturer to dispense water for human ingestion (faucets, drinking fountains, etc.), these SDWA amendments also require that the product comply with the lead leaching requirements of NSF/ANSI Standard 61, Section 9. Under this standard, certified products are limited to 11 parts per billion (ppb) of lead in water from endpoint devices.

Endpoint devices subject to the lead leaching requirements of NSF/ANSI Standard 61 include faucets, hot and cold water dispensers, drinking fountains, drinking fountain bubblers, water coolers, glass fillers, residential refrigerator ice-makers, supply stops, and endpoint control valves.

Codes

There are two primary model codes that have minimum standards for the installation of plumbing systems into the home. These are the Uniform Plumbing Code and the International Plumbing Codel.

UPC - Uniform Plumbing Code
www.iapmo.org

This code provides minimum standards and requirement to safeguard life and limb, health, property, and public welfare by regulating and controlling design, construction, installation, quality of materials, location, operation and maintenance or use of plumbing systems. The provisions of the code apply erection, installation, alteration, repair, relocation, and replacement, in addition to use or maintenance of plumbing systems.

International Plumbing Code (IPC) – International Code Council
www.intlcode.org

The IPC is designed to protect public health and safety through provisions that do not unnecessarily increase construction costs or restrict the use of new materials, products or methods of construction, and without giving preferential treatment to particular types or classes of materials, products, or methods of construction.

Federal Regulations

National Plumbing Products Efficiency Act of 1989

Established national standards for the manufacture and labeling of certain plumbing products in order to conserve and protect water resources.

Related Articles:

AWWA. (2002). "Residential Plumbing Fixture Saturation Study." ACE 2002 Conference Proceedings

Bennet, D. & Mayer, P. (2003) "EBMUD Indoor Residential Water Conservation Study: The Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single Family Homes in the East Bay Municipal Utility District Service Area." ACE 2003 Conference Proceedings.

Mullarkey, N. (1991). "Low Volume Toilet Retrofits in Two Low-Income Public Housing Projects." ACE 1991 Conference Proceedings.

CUWCC. (2003). "Benefits of the United States Nationwide Plumbing Efficiency Standards". Online: http://www.isf.uts.edu.au/whatsnew/PlumbingStandardsPaper.pdf

United States General Accounting Office. (2000). "Water Infrastructure: Waster-Efficient Plumbing Fixtures Reduce Water Consumption and Wastewater Flows: Report to Congressional Requestors." The General Accounting Office. Washington D.C.

EPA Lead and Copper Rule of 1991

Limited the amount of copper and lead found in potable water to .015 (copper) and 1.3 mg (lead).

Related Articles:

Boulay, N. & Edwards, M. (2001) Role of Temperature, Chlorine, and Organic Matter in Copper Corrosion by-product release in Soft Water. Water Res. v. 35. no. 3.

Marinas, B., Benito, J., Connie, L. & Lan H. (1993). Control of Drinking-Water Lead-Contamination Contributed by Brass Plumbing Fixtures. ACE 1993 Conference Proceedings.

Hazan, S., Gebhart, A., Epstien, P. (1994). Evaluation of Mechanical Products and Plumbing Products for Lead Under ANSI/NSF Standard 61. ACE 1994 Conference Proceedings.

Sorg, T., Schock, M., & Lytle, D. (1995). An Evaluation of Ion Exchange Softening on the Leaching of Metals From Housing Plumbing Materials. ACE 1995 Conference Proceedings.

Beets, D. (2002). Lets Get the Lead Out. American Water Works Association Journal. 94, 2.

<u>Components of the Plumbing System</u>

ASTM. (2000). "New Test Method Provides Solid Evaluation of PEX Plumbing". ASTM Standardization News. v. 28 (9).

> ASTM developed a standard to measure the effectiveness of PEX piping. The standard outlines a method for evaluating the oxidative resistance of PEX piping to the effects of chlorinated water. This standard is aimed to evaluate the PEX under very aggressive conditions due to the questionable suitability for application in potable water systems.

Wyly, R. (1984). "Field Hydraulic Performance of One- and Two-Story Residential Plumbing Systems with Reduced-Size Vents". U.S. Department of Commerce, National Bureau of Standards Center for Building Technology.

> This study examined the performance of drain waste vent systems with reduced-sized vents in single-family homes. The vent systems were installed using a procedure tested in a laboratory setting. Measurements were taken to determine the trap seal reduction and pneumatic pressure excursions in selected vents. The study finds that the procedure for reduced sized vent systems showed satisfactory performance and provides recommendations for the updating of codes.

Mason, J. (1996). New Tests to Determine the Causes of Failures in ABS Drain Waste and Vent Plumbing Systems. Thermochimica Acta. v. 272.

In the 1980's the prevalence of ABS DWV system failures started to increase drastically. It was determined that these failures were a result of unacceptable solvent cements that were used to assemble the systems as well as poor quality piping. This article discusses new tests to address these failures. The test protocols are described and applied to the analyze the failures of the ABS DWV systems.

Swaffield, J. & Galowin L.S. (1992). The Engineered Design of Building Drainage Systems. Aldershot, Hants, England. Broolfield, VT., USA.

History of Drainage System and Current Methodologies: The objectives of early drainage systems were simply to prevent odor from entering the home and to supply water to carry waste away. Research conducted in the 1920s equipped designers with the knowledge, particularly with the relationship between stack water flow rate and air pressure loss due to trap seal loss. Hunter's (1924, 1938) research determined that vertical carrying waste stacks should not run more then 25% full in order to prevent the air pressure loss from improper functioning trap seals. During this time Hunter also investigated the necessary size of the vent system. Wyly and Easton (1961) built on Hunter research and also looked at vent systems, their work guided designers and lead to the introduction of the more efficient and economic one pipe system that is still used today in the US and England. In order to reduce complexity of the systems, the Sovent system was developed in Switzerland. This system is a version of the single stack and is now widely used in the USA and Europe.

Toolbase.org. (2004). Plastic Plumbing Manifold. PATH Technology Inventory.

Home Run System is a manifold system that allows all the plumbing connections to be located centrally in one area of the house. Due to the design of this system saving can be achieved in material costs, hot water energy costs, and installation costs. The systems controls water pressure and temperature more efficiently then the current system. Caution should be taken when installing this material in extremely cold climates because the material has the tendency to become stiff and difficult to use.

Field performance tests are also highlighted in this article that was performed on a number of case studies. These case studies highlight the some of the difficulties that may occur when transitioning from traditional plumbing design to this new technology.

Toolbase.org. (2004). Radiant Floor Heating. PATH Technology Inventory.

Dry system radiant flooring is radiant heat installed beneath a finished floor without material poured over the tubing. Several manufacturers offer dry radiant systems that position radiant floor tubing above floor, between two layers of plywood, or below floor under the subfloor. Hydronic radiant floor systems pump heated water through tubing positioned in loops beneath the finished floor. The heated water flowing through the tubes

heats the surrounding air and flooring material. The floor emits energy as a result of its temperature.