# Air Barriers:
## Expectations Versus Reality

**Military housing washes out on new air-barrier standards.**

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**FIGURE 1** Family housing at a military base located in a warm, humid climate didn't pass muster when it came to new standards.

U.S. AIR FORCE PHOTO BY KEMBERLY GROUE

**New building codes** require high-performance, and they encourage sustainability and innovation such as those found in green building rating systems. This article summarizes the air tightness test results from 10-year-old military housing located in a warm, humid climate, and it demonstrates that these air tightness test results approach new air tightness code requirements. However, significant confusion and building failures can ensue from lofty, and perhaps unachievable, benchmarks. This is the current situation that designers and contractors face while trying to meet current wall system air-barrier design and performance requirements.

Overly complex and problematic exterior wall systems due to a market-driven design emphasis on energy savings, high performance and innovation inevitably lead to increased risk and liability, but they also increase concerns about mold and moisture damage in warm, humid climates. This view is supported by the National Institute of Building Sciences in NIBS Guideline 3-2012, "Building Enclosure Commissioning Process," which says that whole-building testing in the U.S. is usually done for research.[1]

Significant in 2012 were two developments by the International Code Council. These included:

- More stringent residential air tightness requirements by the International Energy Conservation Code (IECC) became a mandatory provision to be verified by testing. The more stringent requirement went from 7 air changes per hour (ACH) to 5 ACH in climate zones 1 and 2.[2]
  - Alternatively, homes with higher efficiency HVAC systems may be subject to less stringent whole-house testing.
  - Residential air tightness test studies leading up to 2012 indicated a range in air leakage rates in homes. Despite these ranges in performance, entities like the Department of Energy indicated that homes can be built well-sealed (as studies show) and that new, more stringent requirements would improve the considerable share of homes that have higher leakage rates.
- The issuance of the International Green Construction Code (IgCC). The IgCC represents minimum regulations for safe and sustainable building systems using prescriptive and performance-based approaches.
  - The challenges of the prescriptive approaches are that they are

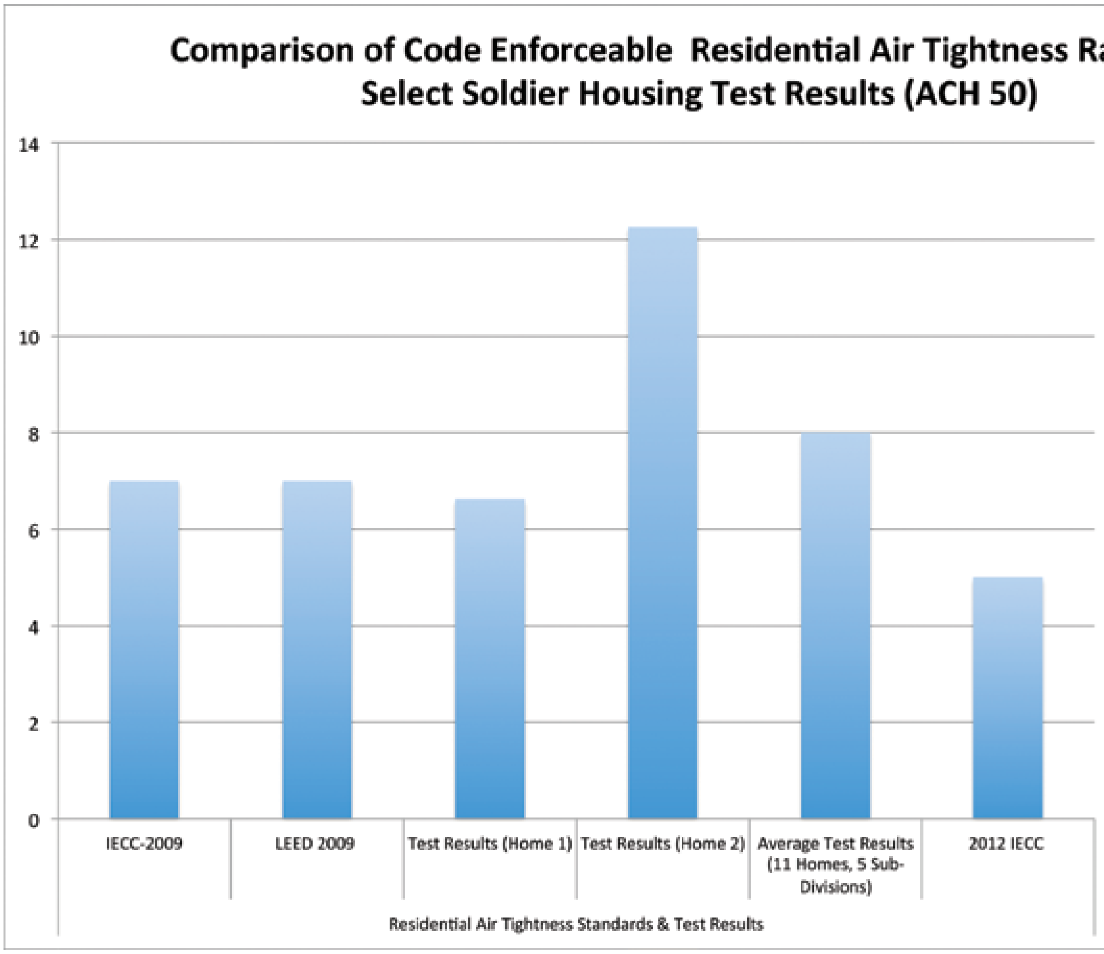


**FIGURE 2**
Comparison of recent codes and standards to test results and the latest code air tightness requirements

IMAGE COURTESY OF LIBERTY BUILDING FORENSICS GROUP

driven by rating systems for high efficiency and innovation, which are unproven.

- The challenges of the performance-based approaches are that they are driven by lab test results that do not translate well to field applications.

## IMPACT ON CONTRACTORS

This codification is then pushed out to contractors, who unfortunately must then face the task of interpreting sometimes puzzling requirements that don't always make sense or work in the field.

Designers are often unfamiliar with how the interaction of air-barrier systems and heating, ventilating, and air-conditioning (HVAC) systems affect compliance and air infiltration, as well as how this interaction can escalate the potential for moisture damage.

Additionally, designers are not generally performing air-barrier tests or evaluations on conditions that are conducive to moisture problems. It is often a combination of factors and nuances that lead to these problems. The causes can be a combination of design, construction or operations.

## IMPACT ON THE DESIGN AND CONSTRUCTION COMMUNITY

Demonstrating and validating air-barrier performance by using quantitative testing methods to comply with new air tightness benchmarks and mandatory testing validation is uncertain and less familiar to the design and construction community for the following reasons:

- Benchmarks and testing validation are new.
- Benchmarks are more stringent than previous requirements.
- Impacts on moisture control may be unknown related to the interaction of the HVAC and building envelope systems.
- Impacts on moisture control may be unknown as it relates to blended requirements for sustainability and innovation.
- Code exceptions can be confusing, and their potential impact on moisture control may not be understood.
- It is uncertain if new benchmarks will be consistently maintained while minimizing conditions conducive to moisture problems.

As a result, our firm, Liberty Building Forensics Group (Liberty), has been called upon on numerous occasions to perform building forensics and diagnostics services on structures suffering from moisture and rainwater problems, especially in warm, humid climates.

Such was the case when we were retained to provide an assessment of moisture-related problems in off-base soldier housing in a warm, humid climate (Figure 1). Specifically, the purpose of this investigatory project was to evaluate these existing military homes to determine the presence of HVAC and

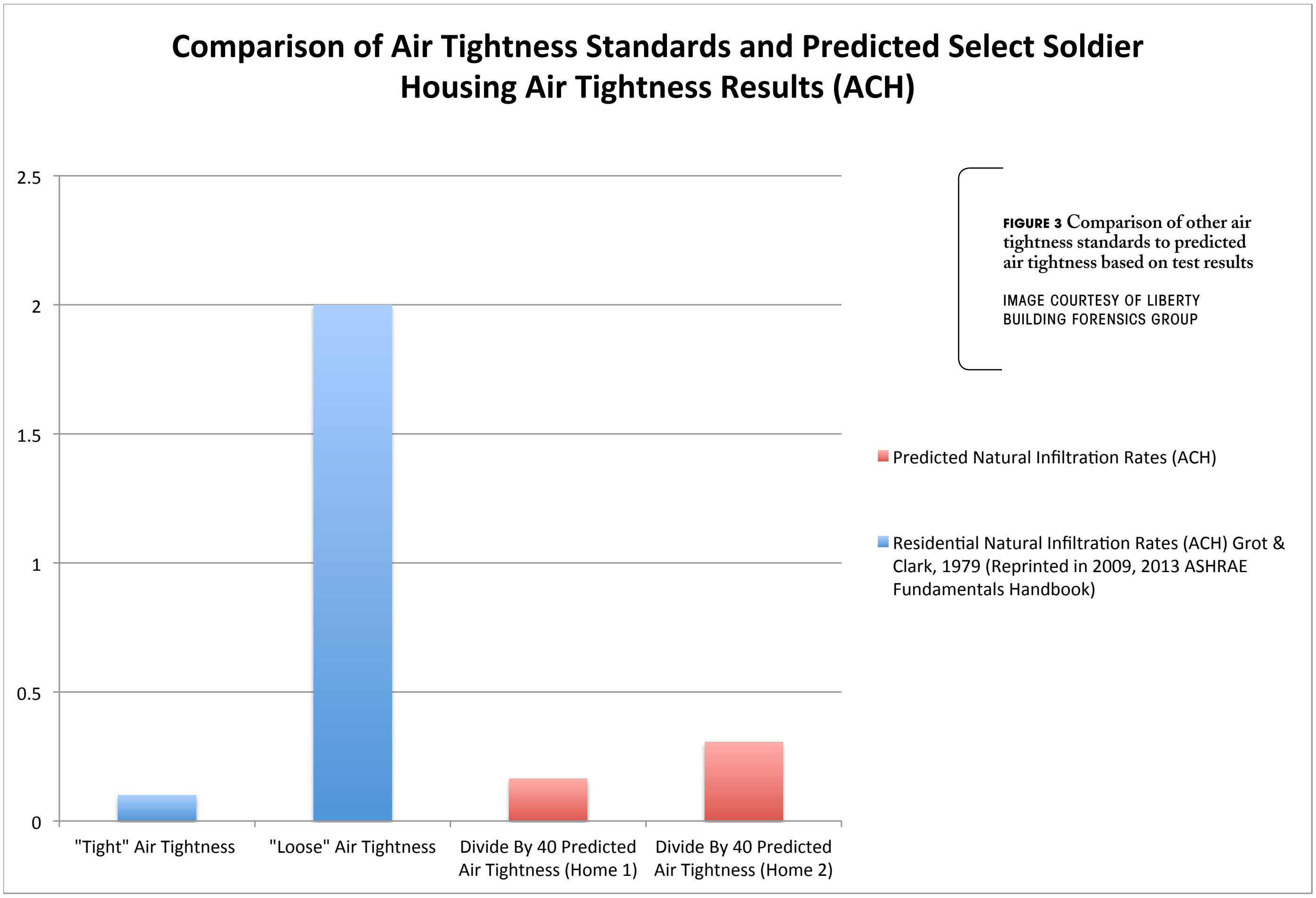


**FIGURE 3** Comparison of other air tightness standards to predicted air tightness based on test results

IMAGE COURTESY OF LIBERTY BUILDING FORENSICS GROUP

building envelope deficiencies (if any). If moisture damage was identified, we were to determine if the cause was water or air.

During the assessment, the HVAC systems in up to 100 homes at this U.S. military base were evaluated, and building envelope testing was performed in up to 30 homes. In addition to visual observations, the following building performance and HVAC diagnostics were completed:

- Test building air tightness
- Evaluate overall home pressurization
- Evaluate entire HVAC system performance

In this article we will focus specifically on the building air tightness component.

## PREVIOUS AIR-BARRIER STANDARDS FOR HOMES

The most recent air-barrier standards for homes that were applied to this project were based on the International Energy Conservation Code (IECC), Leadership in Energy and Environmental Design Homes (LEED Homes 2009), and the *2009 ASHRAE Fundamentals Handbook*. A brief explanation of the requirements in these codes and standards follows.

## IECC AND LEED HOMES 2009

This project was located in Climate Zone 2, which required a 7 air exchange rate (air changes per hour, or ACH) at 50 Pascals (Pa). The new air exchange rate (ACH) standard at 50 Pa is 5 ACH. Refer to Figure 3 (above) for an air tightness comparison of recent standards to the latest code enforceable requirements and to the test results in this project.

## 2009 ASHRAE FUNDAMENTALS

According to ASHRAE in chapter 16 of the *2009 ASHRAE Fundamentals Handbook*, residential ventilation varies by a factor of about 10. Home natural infiltration rates are considered “tight” in construction at approximately 0.1 ACH, while they are considered “loose” in construction at 2.0 ACH. The first study was performed by Grot and Clark in 1979.[3,4]

## “DIVIDE BY 40” METHOD

Several studies such as Grot and Clark, 1979, have been performed on building air tightness throughout the years. These have been driven largely by energy efficiency concerns.[5] These studies are generally initiated by way of grants and appropriated research funds. The largest organization in the U.S. to perform research in the area of renewable energy and energy efficiency is the Florida Solar Energy Center (FSEC). In a 1990 study, the FSEC determined that a “Divide by 40” method provides superior predictive approximation of the natural infiltration rate of air tightness-tested homes.[6] This natural infiltration rate is approximated by taking the tested CFM50[7] or ACH50[8] and dividing by 40. While this method is widely used and recognized by ASHRAE as a means of comparing air tightness testing in homes, it is not considered an air tightness standard.

### FORMER STANDARDS, STUDIES AND PREDICTIVE METHODS COMPARED WITH NEW STANDARDS

Recent code benchmarks are far more aggressive than the previously accepted air-barrier standards, funded studies and grants, and predictive comparative methods. This is illustrated in Figure 3, where the test data results from two homes were applied to the new standards.

> OVERLY COMPLEX AND PROBLEMATIC EXTERIOR WALL SYSTEMS DUE TO A MARKET-DRIVEN DESIGN EMPHASIS ON ENERGY SAVINGS, HIGH PERFORMANCE AND INNOVATION INEVITABLY LEAD TO INCREASED RISK AND LIABILITY, BUT THEY ALSO INCREASE CONCERNS ABOUT MOLD AND MOISTURE DAMAGE IN WARM, HUMID CLIMATES.

### IMPACT OF ENVELOPE LEAKAGE

In the case of the military housing, the first step taken in quantitative testing was conducting a blower door test to check for building envelope leakage. The blower door test results indicated a range of leakiness in the housing envelopes as follows:

- Characterized as tight at 0.2 ACH (49 CFM, on average)
- Adequate to meet code-required ventilation rates in accordance with ASHRAE Standard 62, “Ventilation for Acceptable Indoor Air Quality”
- Able to marginally meet (on average) LEED requirements for envelope air tightness

#### House 1

The blower door test results based on the former standards also confirmed that House 1:

- Was characterized as a tight home
- Exceeded the LEED Home 2009 standard by 5 percent
- Approximated the *2009 ASHRAE Fundamentals*’ lowest range of homes tested in North America at 0.165 ACH, compared with 0.1 for tightest homes tested

#### House 2

In House 2 (characterized as a leaky home), blower door test results also based on the former standards yielded an air tightness rate of 12 ACH at 50 Pa compared with the former and new code requirements of 7 and 5 ACH 50, respectively.

Cumulative test results of up to 30 homes indicated that no additional means were necessary to tighten the envelopes for moisture control considerations. This recommendation was also based on the prior standards and predictive models that were in place at the time of testing. However, based on the new IECC-2012 code, this construction would be considered leaky and would require remediation to tighten the envelope.

### CONCLUSIONS AND LESSONS LEARNED

In general, it was found that building air tightness was not a contributing factor to moisture damage in the soldier housing. However, moisture damage was identified due to mechanical depressurization in the following areas:

- Mechanical room closet with return duct leakage
- Ventilated attic with an exhaust fan
- Excessively leaky air handling unit enclosures
- Leaky air-handling casings

This particular case study speaks directly to air barrier expectations versus reality. New codes that contain new air tightness standards based on energy efficiency initiatives are to be expected, but it remains to be seen if these code benchmarks are attainable through normal construction means and methods. The new quantitative benchmarks for air tightness in homes are far more aggressive than were prior codes and standards. In fact, the tighter homes tested in this study that had passed prior air tightness requirements actually failed and were far from obtaining the level of air tightness required by the new benchmarks in the IECC codes.

A word of caution: Be aware of the codes and standards related to air tightness that are specified and designed into your new homes. edc

1 SUB-ANNEX U.2A: FIELD TESTING CASE STUDY EXAMPLE, NIBS GUIDELINE 2006

2 THREE (3) ACH FOR CLIMATE ZONES 3 THROUGH 8.

3 ADDITIONAL STUDIES BY GRIMSRUD ET AL, 1982

4 PARKER ET AL, 1990, TESTING AVERAGE OF ABOUT 0.25 FOR ENERGY-EFFICIENT HOUSES V. 0.49 ACH RANGE FOR THE CONTROL

5 THE GROT AND CLARK, 1979, STUDY LOOKED AT BUILDING AIR TIGHTNESS IN LOW-INCOME HOMES BEFORE AND AFTER APPLYING WEATHERIZATION TECHNIQUES SUCH AS SEALING STRUCTURAL CRACKS, APPLYING WEATHER STRIPPING, ETC. THESE TEST RESULTS THEN PROVIDED THE BASIS OF COMPUTING ENERGY USE VERSUS COST. (SEE *FUNDAMENTALS OF BUILDING ENERGY DYNAMICS* BY BRUCE D. HUNN, CHAPTER 5, “ENERGY CONSERVATION AND MANAGEMENT STRATEGIES” BY P. RICHARD RITTELMANN, 1996.

6 FLORIDA SOLAR ENERGY CENTER, FSEC-CR-370-90, NOVEMBER 14, 1990. PAGE 39. THE “DIVIDE BY 40” METHOD HAS BEEN SHOWN TO PROVIDE SUPERIOR PREDICTIVE CAPABILITY (BASED ON $R^2$ VALUES) COMPARED TO THE “NORMALIZED LEAK PPROXIMATION” (ASHRAE STANDARD 119-1988) AND THE LBL MODEL (1979 ASHRAE TRANSACTIONS BY M. SHERMAN AND D. GRIMSRUD).

7 AIRFLOW AT A TEST PRESSURE OF 50 PASCALS NORMALIZED BY VOLUME (CFM50=ACH50*VOLUME/60)

8 AIRFLOW AT A TEST PRESSURE OF 50 PASCALS NORMALIZED BY VOLUME (ACH50=CFM50*60/VOLUME)