General Services Administration
Public Buildings Service

GPG-053 | OCTOBER 2023

AUTOMATED BUILDING ENVELOPE SEALING

Increases Airtightness and Reduces Overall Heating and Cooling Demand

Air leakage is a significant driver of energy use within buildings. The U.S. Department of Energy estimates that it accounts for approximately 4% of building energy use in the United States. [1, 2] Air leakage also negatively impacts thermal comfort, indoor air quality, and mechanical ventilation systems operation. Typical manual air sealing with spray foam and weather stripping can increase airtightness between 6% and 17%.[3]

Automated envelope sealing is automatically drawn to leaks, removing human error and reaching inaccessible areas. Researchers from the Oak Ridge National Laboratory (ORNL) evaluated automated air sealing during a renovation at an office building at the Denver Federal Center (DFC). Researchers found that the technology increased airtightness by more than 50% from an already airtight envelope.

The largest potential for cost savings is when heating, ventilation, and air conditioning (HVAC) equipment is downsized along with envelope tightening. Researchers estimated that HVAC equipment costs could drop by 70% when tightening a leaky envelope. A sealed building envelope reduces overall heating and cooling demand, supporting GSA's climate goals and enabling low-cost building electrification. It should be considered for all new construction and major renovation projects in GSA's portfolio.

INTRODUCTION

Automated envelope sealing can help meet building airtightness standards

Standards	Requirement (CFM/ft²)	DFC Testbed
GSA PBS P-100 and IECC 2021C402.5.3	0.40	
P-100 Tier 1 high performance	0.25	Baseline 0.23
P-100 Tier 2 high performance	0.15	
P-100 Tier 3 high performance	0.10	Automated air sealing 0.11

"Sealing the building envelope is integral to reducing heating and cooling loads and reaching our net-zero goals. We see the biggest bang for our buck if we can reduce the size of our HVAC equipment at the same time as we seal the envelope, demonstrating the effectiveness of technology stacking."

– Tyler Cooper
Mechanical Engineer
Denver Federal Center
U.S. General Services Administration

What Is This Technology

ATOMIZED SEALANT IS AUTOMATICALLY DRAWN TO LEAKS

This technology seals the building envelope by pressurizing it, using a modified blower door, and then distributing an atomized, non-toxic, water-based sealant that is automatically drawn to leaks. Before deploying the system, all finished horizontal surfaces, and openings that shouldn't be sealed, are covered. The space is then pressurized, and a wireless mesh network controls an array of nozzles and distributes sealant by following the air leaking from the building. The sealant particles, which are ultra-low volatile organic compounds (VOCs) with no off-gassing, build on each other incrementally, closing envelope leaks to the degree specified by the system software. The system can seal holes up to ½" in diameter. Temperature, air pressure, and humidity are monitored in real-time while controlling the distribution of sealant. Once the sealing procedure is completed, the space can be re-entered within 30 minutes. The automated air sealing for this evaluation was provided by Aeroseal.

What We Did

RESEARCHERS MEASURED DATA COMPARED TO MODELED PERFORMANCE

In 2022, automated envelope sealing technology was installed during a major renovation of Building 40, a two-story, 46,000 ft² office building at the DFC. The technology was tested in 4,461 ft² of space in the west wing of the 2nd floor. In preparation for the sealing, two temporary walls were installed, and intentional openings, such as electrical outlets and fan vents, were covered. Independent blower door tests were performed before and after sealing. Researchers used the measured airtightness results to simulate energy savings across ASHRAE climate zones with different levels of airtightness: leaky (1.2 CFM/ft²), medium (0.4 CFM/ft²), tight (0.25 CFM/ft²), and building sizes: small 1-floor, medium 3-floor, large 2-story, and large 12-story. The small and large 12-story buildings were modeled using EnergyPlus simulations, and the medium and large 2-story buildings were modeled using ORNL's air infiltration calculator. Researchers also interviewed building staff and assessed the ease of installation and overall cost-effectiveness.

FINDINGS

INCREASED AIRTIGHTNESS BY 53% From an already tight envelope of 0.23 CFM/ft^2, meeting GSA's PBS-100 standards for Tier 1 high-performance buildings, to 0.11 CFM/ft^2, meeting Tier 3 performance standards.

LARGEST SAVINGS FOR LEAKY BUILDINGS IN COLD CLIMATES The baseline airtightness, climate, and building type all impact savings. As expected, leaky buildings in cold climates with more exposed surface areas showed the most significant heating, ventilation, and cooling (HVAC) savings: 11 kWh/ft^2, 41% for electricity, and 81% for natural gas. Mixed-mild climates like San Francisco and Los Angeles had the lowest savings (< 0.8 kWh/ft^2).

In similar heating/cooling climates, humid climates showed two times greater savings because HVAC systems use additional energy for dehumidification. Modeled savings were also impacted by exterior surface area, window-to-wall ratio, building height and mechanical equipment.

REDUCED HVAC CAPACITY REQUIREMENTS Automated air sealing can reduce the required size of HVAC equipment. In the modeling for tightening a leaky, large 2-story building, the required HVAC capacity was reduced by 71%. Assuming costs of $166 KBtu/hr for an electric heat pump, the capital cost of HVAC equipment can be reduced by ~$500K.

INSTALLATION AND CLEANUP < 1 DAY The sealing process, which covered 4,461 ft^2 of the building, was completed within two and a half hours. The entire process took just under 7 hours, including preparation, sealing, and cleanup. GSA staff found no issues post-installation.

COST-EFFECTIVE WHEN SEALING A LEAKY ENVELOPE Based on energy savings alone, automated air sealing can be cost-effective when applied to leaky buildings in cold climates. If the building is already tight, as was the case at the DFC, the technology will not likely be cost-effective. Payback at the DFC was greater than 100 years, even with the 53% increase in airtightness. If the baseline had been leaky, payback would have been less than 10 years.

CONSIDER FOR NEW CONSTRUCTION AND GUT RETROFITS Automated air sealing is best suited to new construction or gut retrofits. It is possible to apply the technology to finished spaces, but because of the additional prep work to cover and protect surfaces and remove furniture, it costs about twice as much, $2.50/ft^2 versus $1–$1.25/ft^2. (Since the evaluation was completed, costs have decreased to $1.75/ft^2 for finished space and $0.90-$1/ft^2 for constructed space.) Applicable to historic buildings and may be particularly effective for brick, concrete, and limestone façades where other insulation methods are not possible.

Savings dependent on building leakage, climate, exposed surface area

Airtight buildings not cost-effective based on energy savings alone

Location		Leaky Baseline (1.2 CFM/ft^2)*			Tight Baseline (0.25 CFM ft^2)**		
CLIMATE ZONE	CITY	ELECTRICITY Savings kWH/ft^2/yr	GAS Savings kBtu/ft^2/yr	PAYBACK Years	ELECTRICITY Savings kWH/ft^2/yr	GAS Savings kBtu/ft^2/yr	PAYBACK Years
2B	Phoenix, AZ	0.29	0.57	31	0.03	0.07	293
4B	Albuquerque, NM	0.07	5.37	21	-0.02	0.48	566
4C	Seattle, WA	0.10	9.35	12	0.00	1.16	112
5A	Chicago, IL	0.79	19.27	5	0.04	2.21	48
6A	Minneapolis, MN	2.03	31.74	2	0.10	3.40	28

*Assuming an installed cost of $1.25 ft^2 for a 2-story, 210,887 ft^2 building and average GSA utility rates of $0.12/kWh for electricity and $9.6/MMBtu for gas
**IEC Guidelines and GSA PBS-P100 baseline standard for envelope infiltration: 0.4/CFM/ft^2

CONCLUSIONS

These Findings are based on the report, "Automated Air Sealing Demonstration: Denver Federal Center Building 40," which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

Footnotes

[1] U.S. EIA. 2023. U.S. energy facts explained. Accessed 08-2023.

[2] DOE EERE. 2014. Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies.

[3] D. Bohac, M. Hewett, J. Fitzgerald, J. Novacheck, and A. Lutz. 2014. "Leakage Reductions for Large Building Air Sealing." International Journal of Ventilation 12, No. 4 : 307–316.

Technology for testbed measurement and verification provided by Aeroseal.

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What We Concluded

SUPPORTS BUILDING ELECTRIFICATION AND GSA CLIMATE GOALS

High-performing envelopes are the most effective way to reduce a building's heating and cooling demand and will be key to meeting GSA's ambitious goals for a 65% reduction in operational GHG by 2035 and net zero by 2045. A tighter envelope allows for smaller HVAC equipment and can significantly reduce capital expenditures as GSA shifts to all-electric buildings. Researchers found that automated air sealing performed well and reduced air infiltration by 53% from an already tight envelope. Modeling demonstrated that buildings with higher leakage rates, large exterior exposed areas, and colder, more humid climates would have the highest energy savings. It should be considered for all new construction and major renovation projects in GSA's portfolio.

Lessons Learned and Best Practices

- **Specify in the design phase.** By specifying automated air sealing early in the design process, additional cost reductions for HVAC capacity and insulation can be realized, increasing the opportunities for a positive return on investment.
- **Savings are site specific.** Calculations of potential savings should be made before implementing this technology. Energy savings are highly dependent on building leakage, climate, and exposed surface area.

Entry Points for Automated Air Sealing

PRE-INSULATION/POST-ELECTRICAL, MECHANICAL, DATA, AND PLUMBING

- Can reduce the overall cost of insulation because the technology acts as a replacement insulator and enables less expensive insulation (i.e., fiberglass, cellulose, or Rockwool) to be used instead of spray foam. It can also reduce the cost of interior caulking, acoustical sealants, and gaskets for electrical boxes, plumbing penetrations, and data boxes.
- Provides the biggest airtightness impact because it can reach the furthest exterior spaces.
- If using fiberglass insulation, it's best to use automated air sealing before insulating, or after drywall.

POST-INSULATION/PRE-DRYWALL

- Can fix problems with spray foam insulation if it has delaminated from the framed structure.

POST-DRYWALL (MUD/TAPE)

- Can correct the envelope's air or vapor barrier that may have been removed or damaged during construction.
- Most common entry point because it provides the most flexibility in the construction schedule.