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Remote Duct Sealing in Residential and Commercial Buildings:

"Saving Money, Saving Energy and Improving Performance"

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Lawrence Berkeley National Laboratory

Berkeley Lab

Presentation Overview

- **Introduction to Duct Leakage**
  - Single-family residences
    - leakage rates, energy impacts, other impacts
  - Larger buildings
  - Duct leakage in codes, standards and utility programs
- **Diagnosing and Repairing Duct Leakage**
  - Leakage testing
  - Aerosol-based duct sealing
    - Technology
    - Single-family residences
      - low-income weatherization to new construction
    - Larger buildings
- **National Impacts**

National Energy-Use Overview

- **Residential – 2005** **- 9.4 Quads**
  - Space heating - 6.7 Quads
  - Space cooling - 2.7 Quads

- **Commercial - 2005** **- 6 Quads**
  - Space Heating - 2.6 Quads
  - Space Cooling - 2.3 Quads
  - Ventilation - 1.1 Quads
- **One Quad = $10-20B**
- **More than 50% of this energy use passes through ducts**

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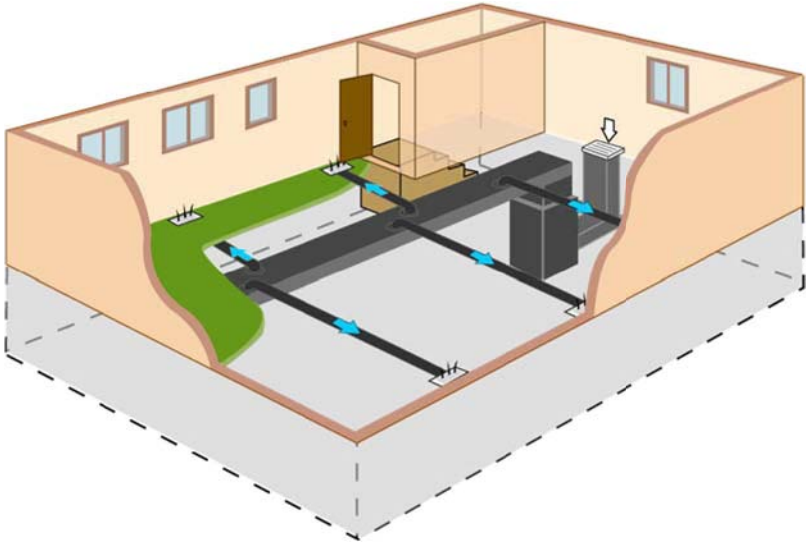
Residential Duct Leakage



Basement Ducts

- Rectangular metal ducts
- Many joints = many leaks
- ~30% leakage on each side of fan
- 50% recovery of lost energy
- Un-insulated = grille temperatures impacted by leaks

Attic/Crawlspace Ducts

- Round metal or flex ducts
- Less joints = less leaks
- ~15% leakage on each side of fan
- Insulated, but outside = 90% of lost energy not recovered

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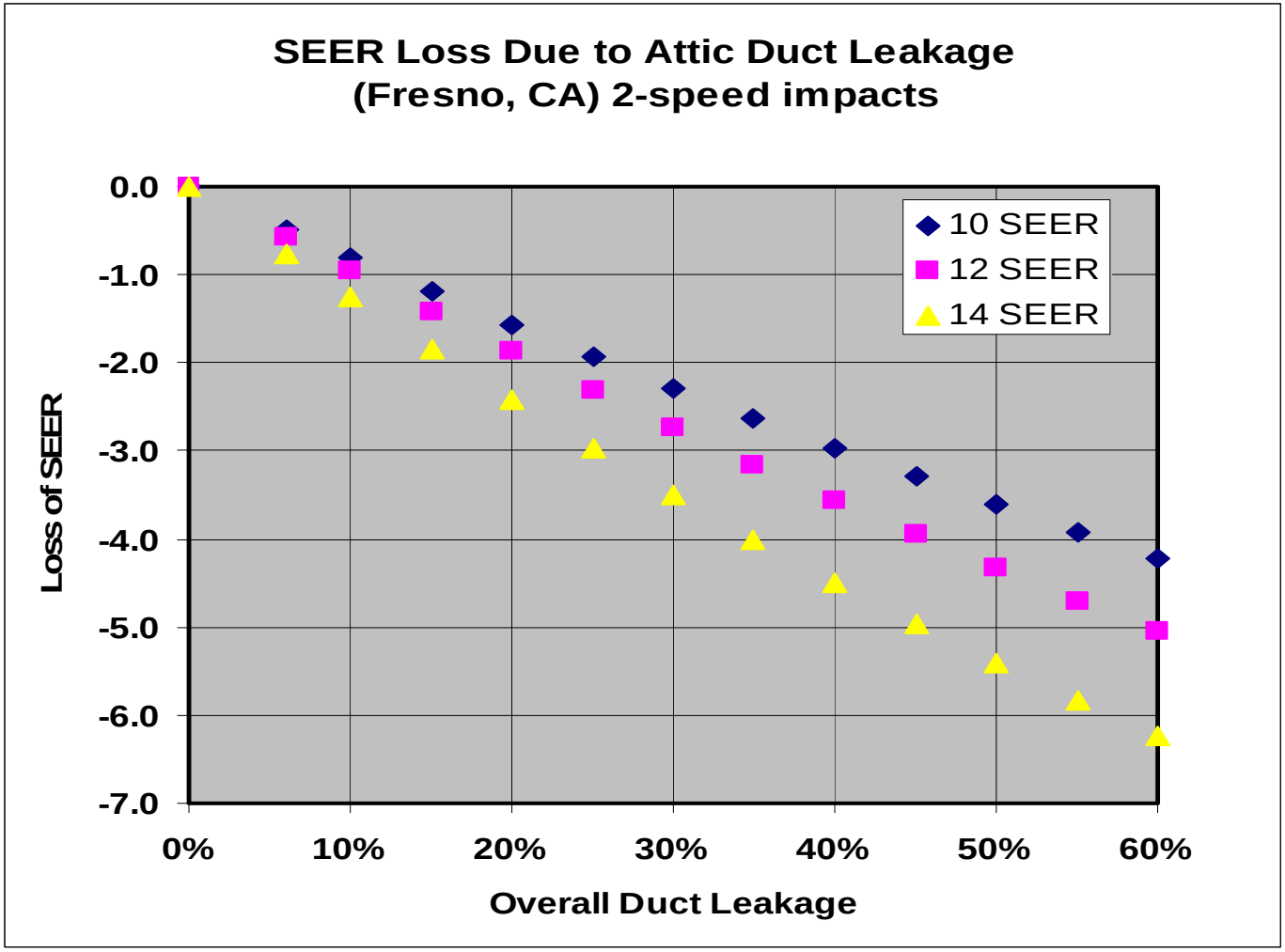
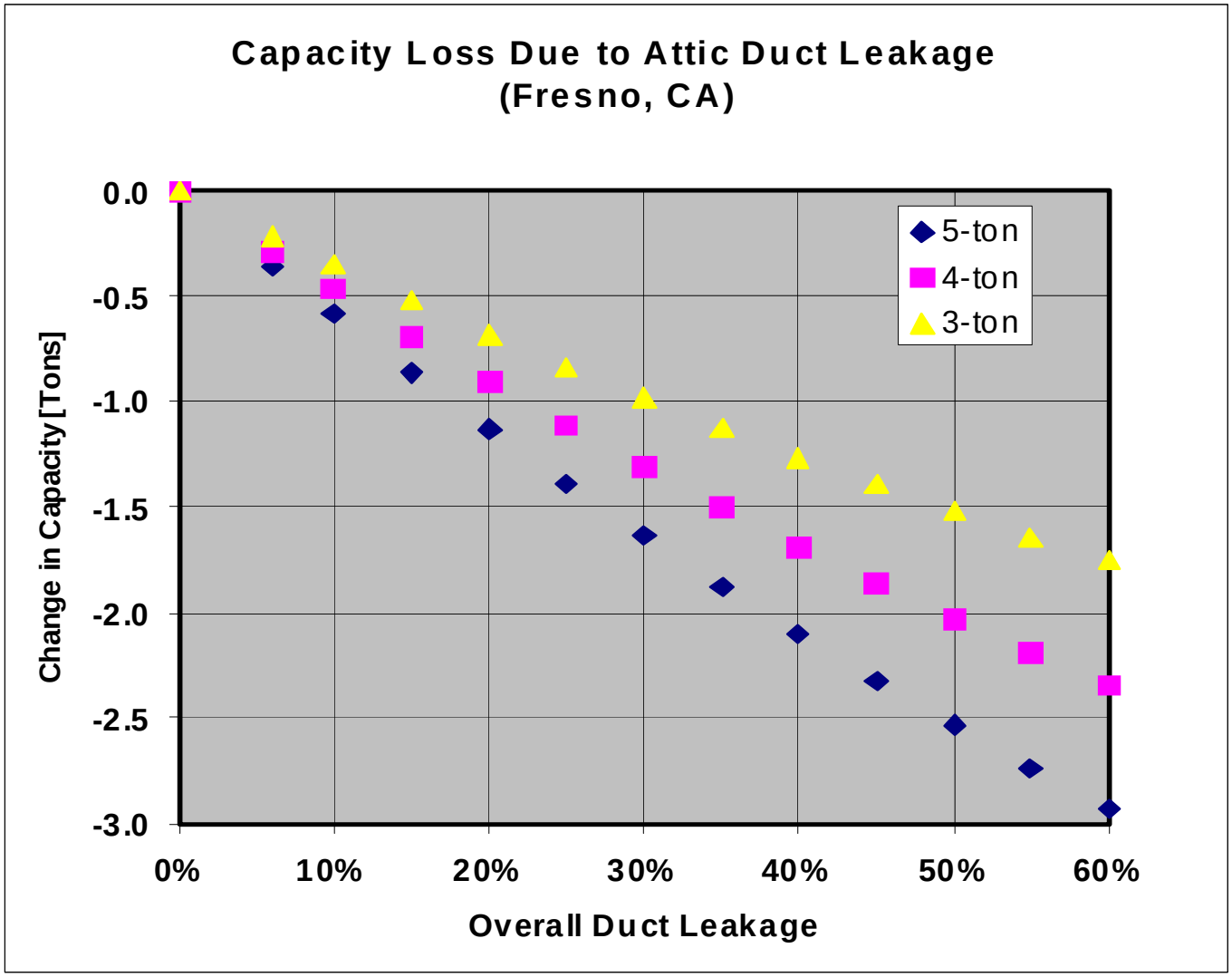
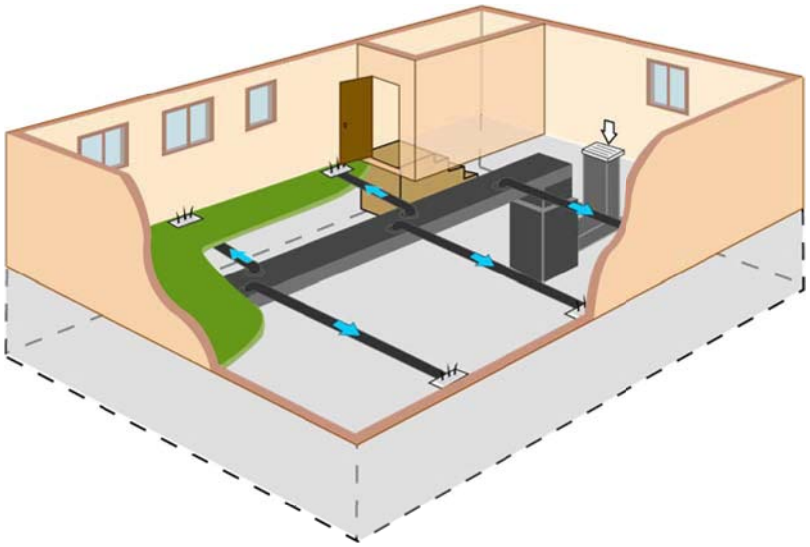
Residential Duct Leakage



Residential Duct Leakage



Savings from Sealing Residential Duct Leakage



Basement Ducts

- Heating/Cooling energy savings from duct sealing **~10%**

Attic/Crawlspace Ducts

- Heating/Cooling energy savings from duct sealing **~15-20%**
- Peak electricity demand savings from duct sealing **25+%**

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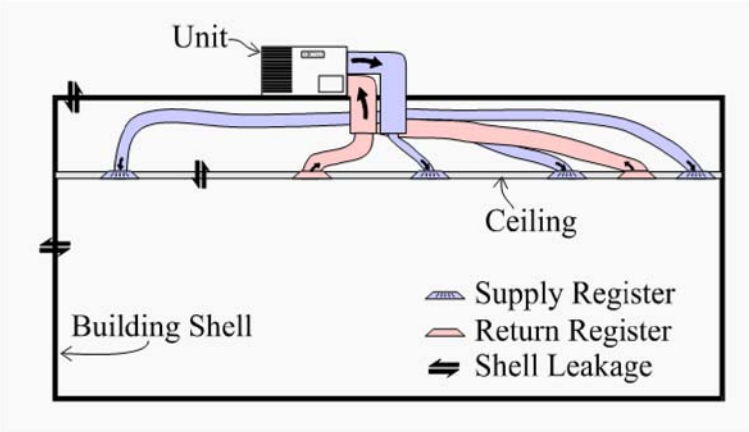
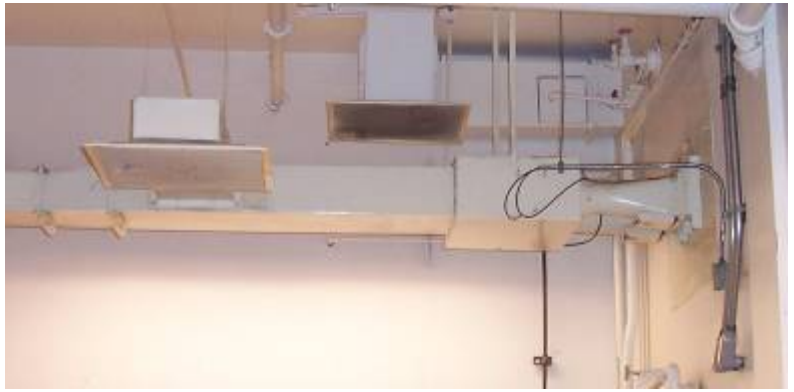
Duct Leakage - Large Buildings

- Impacts depend on Building/System Type
  - Small Rooftop Packaged Units
    - Thermal losses from ducts above ceiling insulation
  - Exhaust Systems (Toilet, Sleeping Rooms, Laboratory)
    - Fan power scales with cube of flow rate
    - Extra flow creates extra heating and cooling loads



Duct Leakage - Large Buildings

- Impacts depend on Building/System Type
  - Office VAV Supply System
    - Leaks act a short circuit to fan
    - Fan power scales with flow rate to power 2.4
  - Laboratory/Hospital Supply Systems
    - Fan power impacts
    - 100% outside air creates large heating/cooling loads



Duct Leakage - Large Buildings

- Why care about duct leakage in an office building?
  - Maintain tenants
    - reduce energy costs
    - reduce complaints
  - Address increased loads

- Why care about duct leakage in a hospital or manufacturing facility?
  - Airflow safety
    - spread of contaminants and biohazards
    - smoke, pressure and humidity control
    - clean-up after contamination
  - Energy savings (100% outside air)

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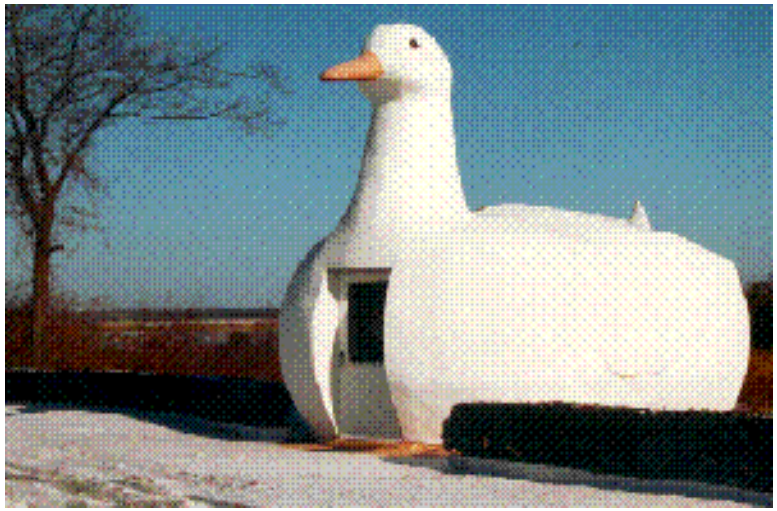
Duct Leakage - Large Buildings



- Why care about duct leakage in a hotel, dormitory or apartment building?
  - Kitchen and Bath Exhaust
    - Excessive fan power and heating/cooling loads
    - Tenant complaints (smoke, smells, moisture)
    - Ventilation and safety codes

Large-Building Exhaust Duct Leakage

Building	Fan Flow [cfm]	Leakage [%]	Notes
Condominium (40-Story)	950	74%	Building-Cavity Bathroom Exhaust
NYS University Dorm (10-story)	2,300	70%	Bath/Shower Exhaust
NYS University Dorm (7-story)	2,050	54%	Bath/Shower Exhaust
Navy BEQ (10-story dorm)	6,300	18%	Ducted Supply w/heat wheel
Navy BEQ (10-story dorm)	6,470	54%	Building-Cavity Exhaust w/heat wheel
Barracks (8 3-story buildings)	20,000	20%	Bath/Shower Exhaust
Office Toilet Exhaust (3-story)	8,700	9%	No pre-qualification of leakage
Hospital Exhaust (9-story)	8,200	19%	Sterilization room riser
Seven NYC Apartment Exhausts	2,450	36%	Kitchen/Bath Exhausts
AVERAGE		**39%**	

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Exhaust Duct Leakage Impacts

- **Fan Power and Thermal Losses**
  - **Pressure varies with square of flow for ventilation**
  - **Duct leaks and/or imbalances create a need to move more air to meet minimum zone flow requirements**
  - **Example**
    - **– 36% exhaust leak ⇨ 56% excess flow ⇨**
    - **– 281% excess fan power**
    - **– Sealing 86% of leakage ⇨ 69% reduction in fan power PLUS**

      15% reduction in heating/cooling loads from exhaust

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Savings Opportunity for Multifamily Exhaust

- **Change in New York City codes allow lower bath and kitchen exhaust flows**
  - **CURRENT**
    - **20 CFM bath**
    - **25 CFM kitchen**
  - **PREVIOUS**
    - **50 CFM bath**
    - **~100-150 CFM kitchen**

- **Flow imbalances and leaky ducts make it hard to capture energy savings from reducing exhaust fan flow**

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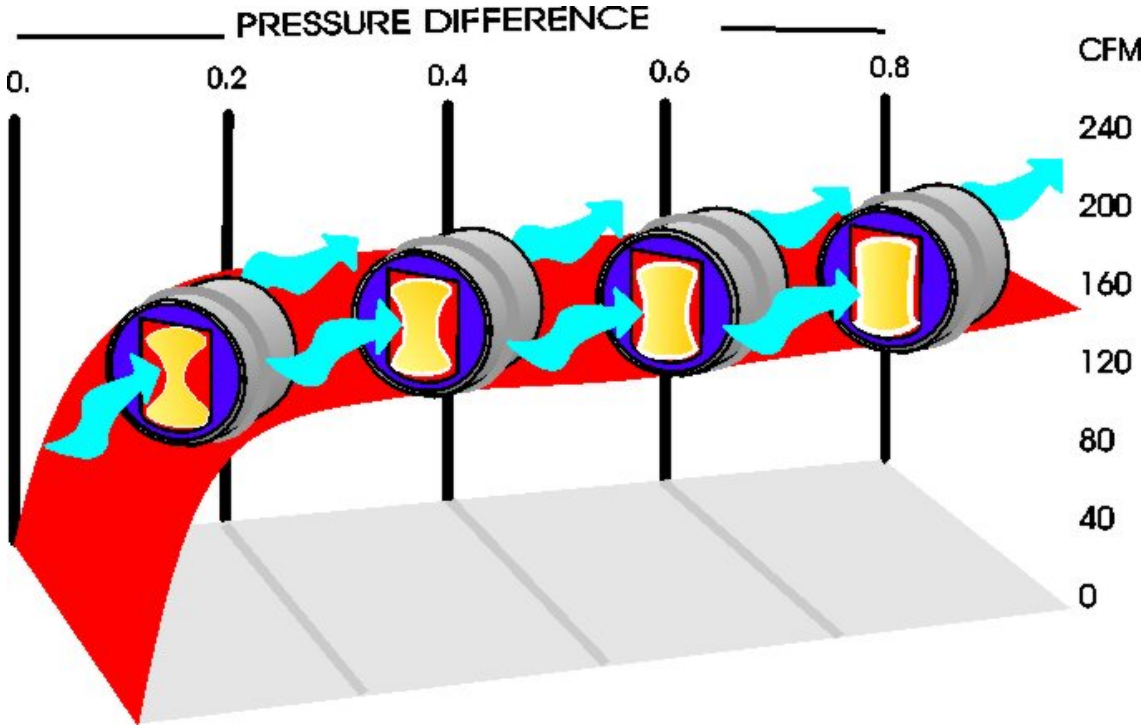
Integrated Solution for Multifamily Exhaust

- **Constant-Flow Grilles** maintain pressure-independent flow, but require a minimum pressure to work



- **Leaky Ducts** cannot maintain adequate grille pressures without increasing leakage and fan flow dramatically, thereby wasting energy

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Integrated Solution for Multifamily Exhaust

- Economics of reducing **36%** leakage by **86%** for **175 cfm** of total kitchen plus bathroom exhaust from an apartment (measured at the roof pre-sealing)
  - Keeping the same apartment exhaust flows after sealing
  - At **$0.15/KWH** for fan, **$0.2/KWH** for air conditioning, and **$1.5/Therm**
  - Savings is **$208/year per apartment**
  - To realize **2-year payback**, can pay up to **$1250 per shaft** sealed
- Economics of reducing **112 cfm** (post-sealing) of total kitchen plus exhaust from an apartment (measured at the apartment) to **45 cfm**
  - Using same utility rates, and duct pressure increase from 25 to 50 Pa
  - Savings is **$130/year per apartment**
  - To realize **2-year payback**, can pay up to **$130 per CAR grille** installed

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Measured Savings in Office Buildings

- **California Office Building**
  - LBNL study of Sacramento Office Building
  - **25-35%** increase in fan energy use due to **15%** duct leakage added on top of **5%** leakage
- **Florida Office Building** (Ceiling-Plenum Return)
  - **5.4** year payback from measured savings in Navy Office Building from sealing **92%** of **19%** leakage downstream of VAV boxes

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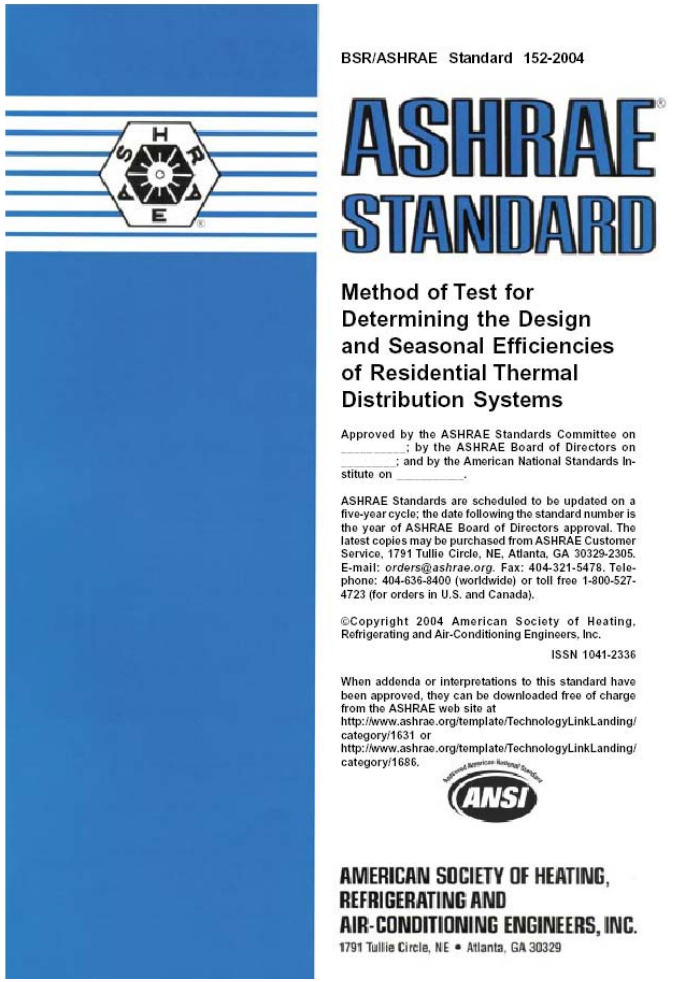
Duct Leakage in Codes, Standards and Utility Programs

- **California Title-24 Energy Efficiency Code**
  - Has required duct leakage testing and sealing since 2001
  - Expanded requirements to existing duct systems in 2005
  - Complicated enforcement mechanisms
- **Other States**
  - Some requirements, but uneven enforcement

Duct Leakage in Codes, Standards and Utility Programs

- **Industry Standards**
  - **SMACNA**
    - *HVAC Leakage Test Manual:* leakage upstream of VAV boxes
  - **ACCA**
    - *Manual J* now includes loads from duct leaks
  - **ASHRAE**
    - *Standard 152* determines overall impacts of leaks, location and insulation



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Duct Leakage in Codes, Standards and Utility Programs

- **Utility Programs for Duct Sealing**
  - Many residential programs in California
    - 7-year residential Aeroseal program by SMUD
    - 1-year light commercial program by SCE
    - Current utility programs help code enforcement
  - Florida, North Carolina and Texas
    - residential programs
  - New York
    - Recent NYSERDA interest in multifamily program
  - Other states??

Diagnosing and Repairing Duct Leakage

Diagnosing Residential Duct Leakage

Diagnosing Duct Leakage – Large Buildings

- Test and Balance Reports
  - Discrepancy between fan and grille/floor flows
- Direct Leakage Measurement
  - Downstream of VAV boxes
- Leakage Indicators
  - Inadequate flow performance
  - Visual/sensual evidence

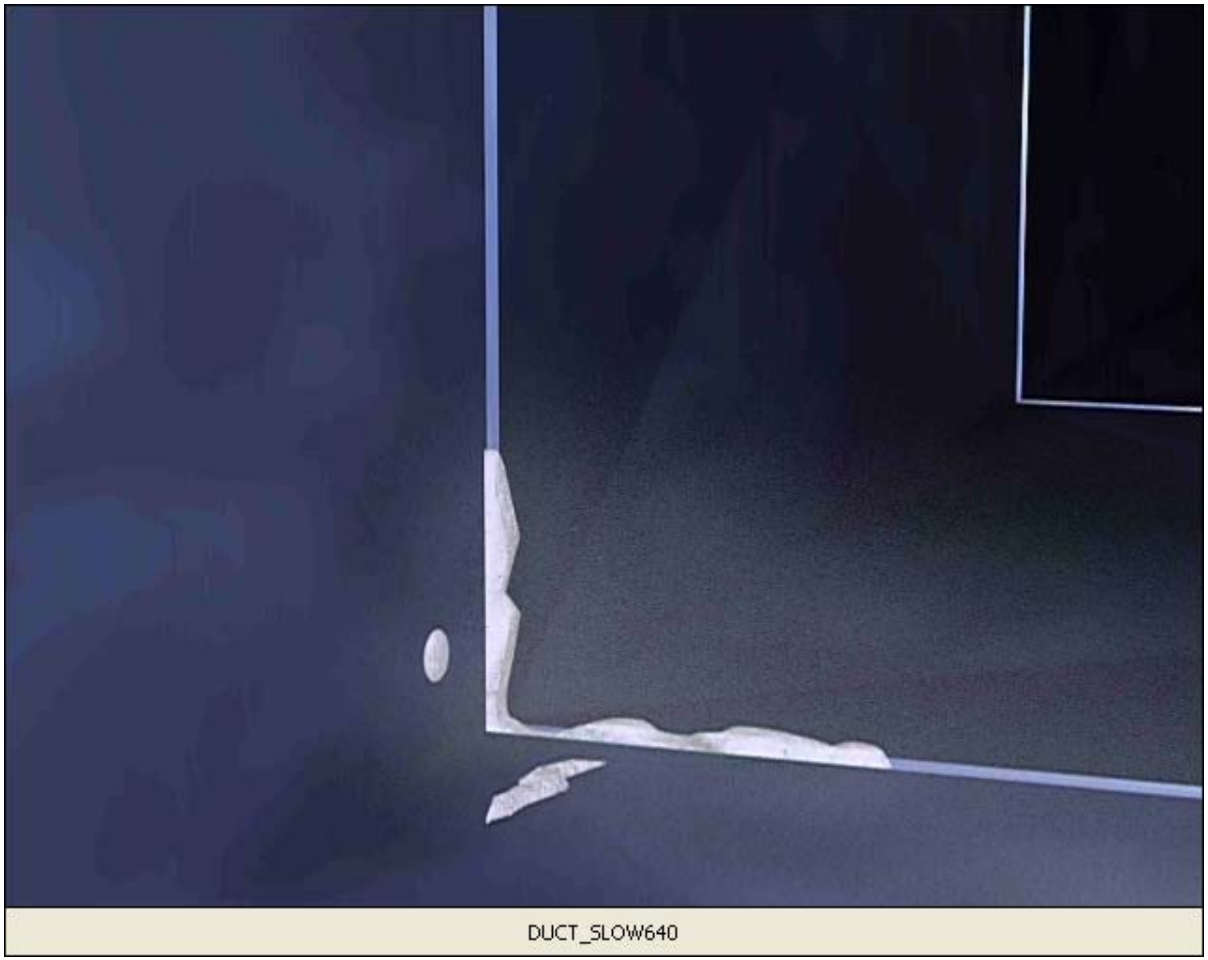
Diagnosing Duct Leakage – Large Buildings

- Large Commercial Supply Leakage Diagnosis
  - **Simplified Fan Pressurization for Leakage Downstream of VAV Boxes**

Diagnosing Duct Leakage – Large Buildings

- Exhaust Leakage Diagnosis
  - **Option 1**
    - **Block all grilles with exhaust fan running**
    - **Measure pressure at midpoint**
    - **Measure flow leaving exhaust system**
      - **time to fill a bag, exit velocity traverse, tracer gas dilution**
  - **Option 2**
    - **Block all grilles with exhaust fan running**
    - **Measure pressure at several grilles (e.g. top, bottom, middle)**
  - **Option 3**
    - **Measure suction pressure at all or multiple grilles during normal operation**

Repairing Duct Leakage: Aerosol Sealing



Repairing Duct Leakage: Aerosol Sealing

Aerosol Sealing Technology

Yellow end

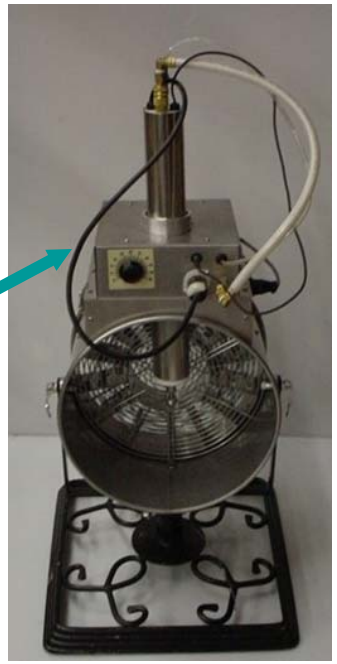
Green end

Blue end

25 foot

50 foot

Red end



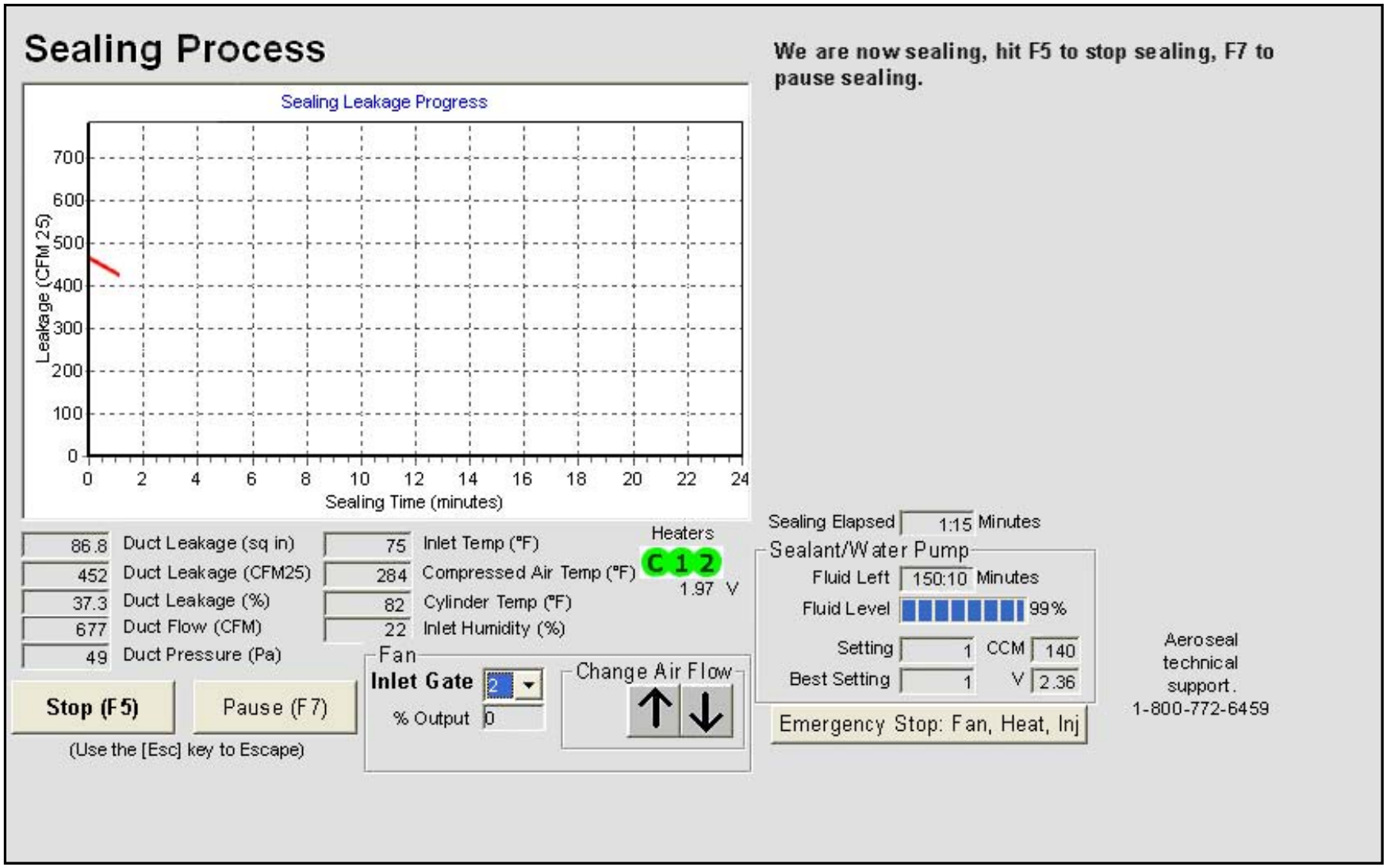
Aerosol Sealing Technology

- Does not coat the ducts
- Vinyl polymer is safe
- No lingering odors or off-gassing
- Lasts 10+ years
- Seals holes up to 1/2” across
- Sealant remains rubbery
- Need not clean before sealing
- Cleaning after sealing generally does not hurt seals

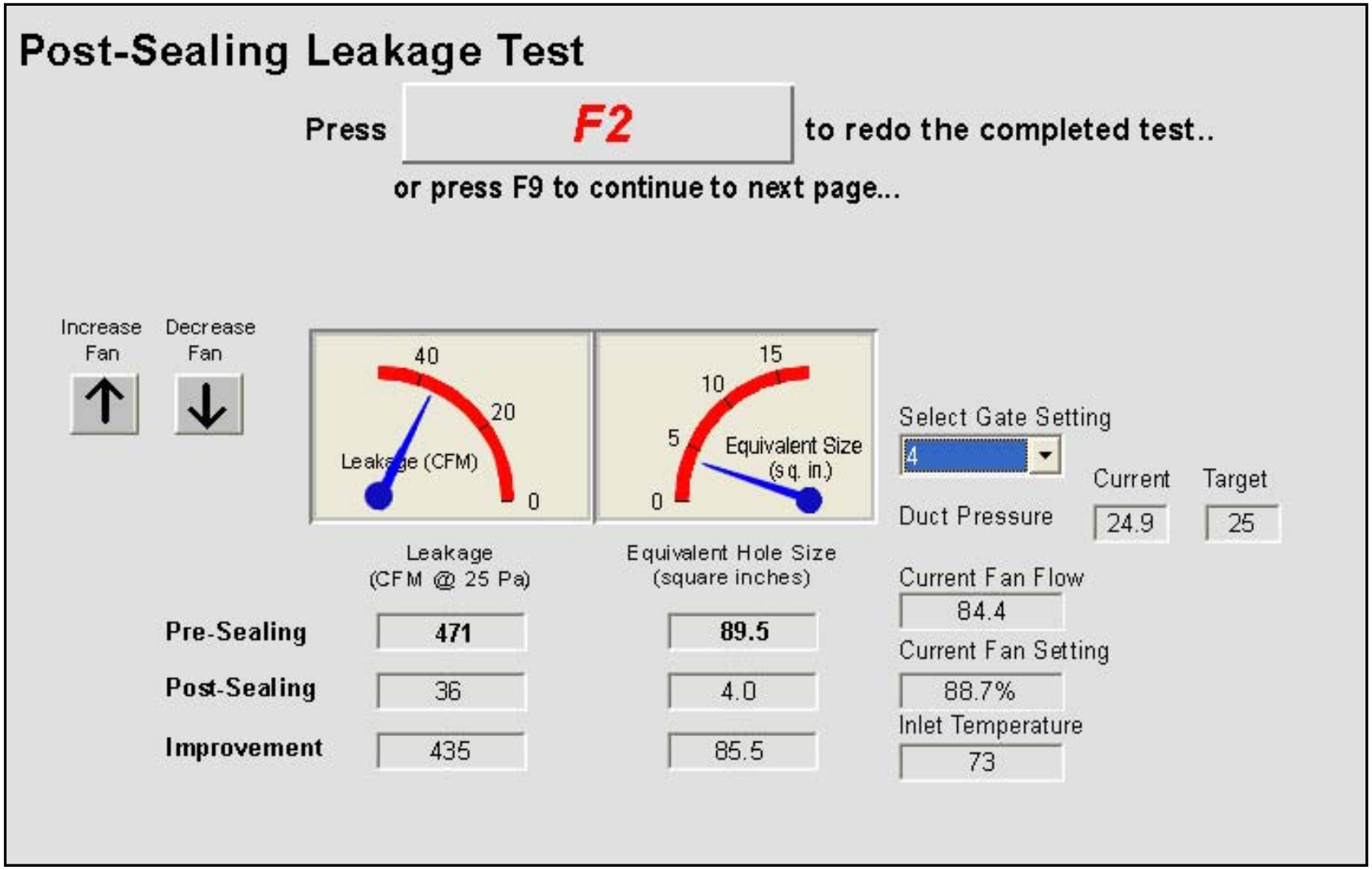
Aerosol Sealing Technology

- California Utilities (CIEE), EPRI, DOE and EPA fund Duct Research at Lawrence Berkeley National Laboratory (LBNL)
- 1994 – research yields Aerosol Sealing Technology Patent
- 1997 – Mark Modera (inventor) founded Aeroseal and received exclusive license
- 1999 - First applications by HVAC dealers
- 2001 – Aeroseal purchased by Carrier Corporation
- 2003 – Carrier-Aeroseal obtained large commercial license from LBNL
- More than **25,000** residential systems have been sealed to date

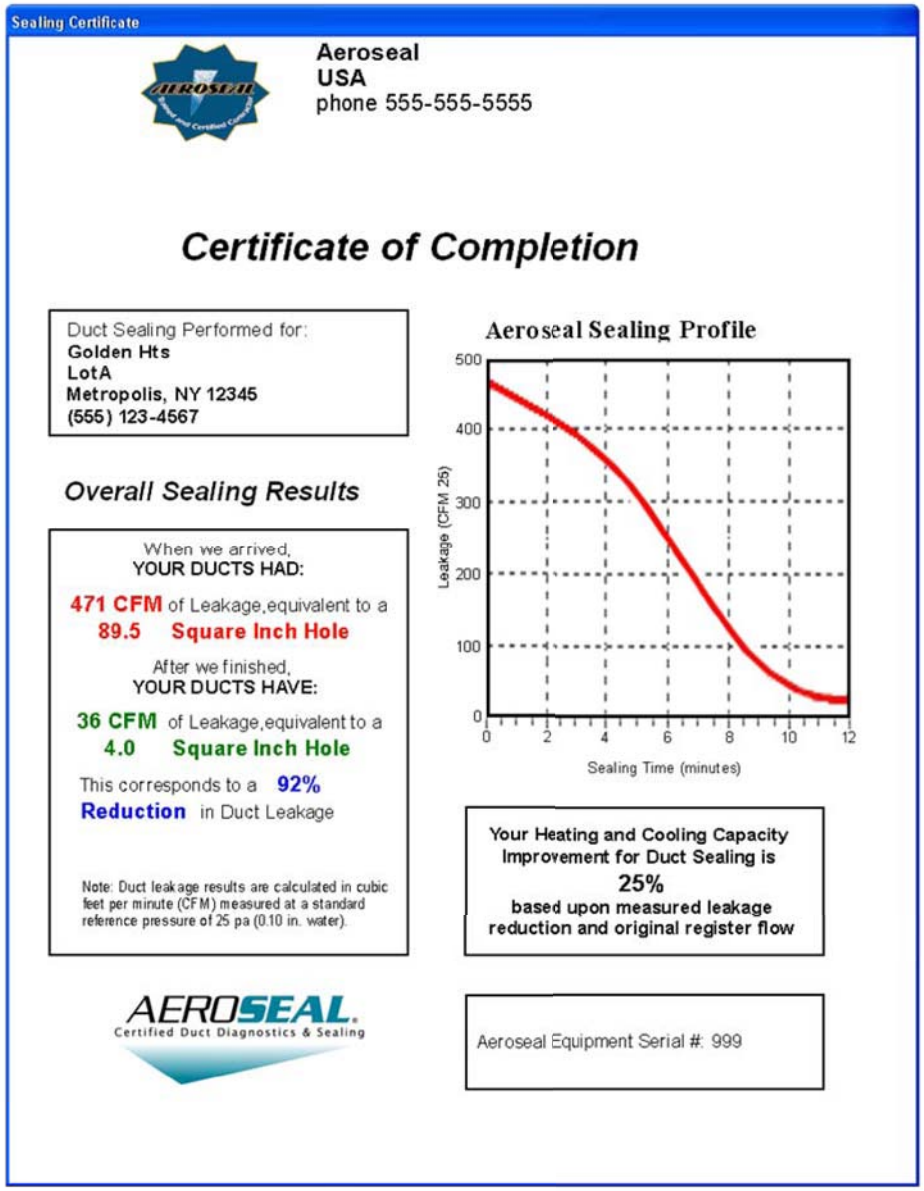
Aerosol-Sealing Technology



Aerosol-Sealing Technology



Aerosol-Sealing Technology


Sealing Certificate

Aeroseal
USA
phone 555-555-5555

Certificate of Completion

Duct Sealing Performed for:
Golden Hts
LotA
Metropolis, NY 12345
(555) 123-4567

Overall Sealing Results

When we arrived,
YOUR DUCTS HAD:
471 CFM of Leakage,equivalent to a
89.5 Square Inch Hole

After we finished,
YOUR DUCTS HAVE:
36 CFM of Leakage,equivalent to a
4.0 Square Inch Hole

This corresponds to a 92%
Reduction in Duct Leakage

Note: Duct leakage results are calculated in cubic feet per minute (CFM) measured at a standard reference pressure of 25 pa (0.10 in. water).

Aeroseal Sealing Profile

Your Heating and Cooling Capacity Improvement for Duct Sealing is
25%
based upon measured leakage reduction and original register flow

AEROSEAL
Certified Duct Diagnostics & Sealing

Aeroseal Equipment Serial #: 999

- **Automatic documentation**
- **Uploads all data over internet**

Residential Aerosol-Sealing Applications

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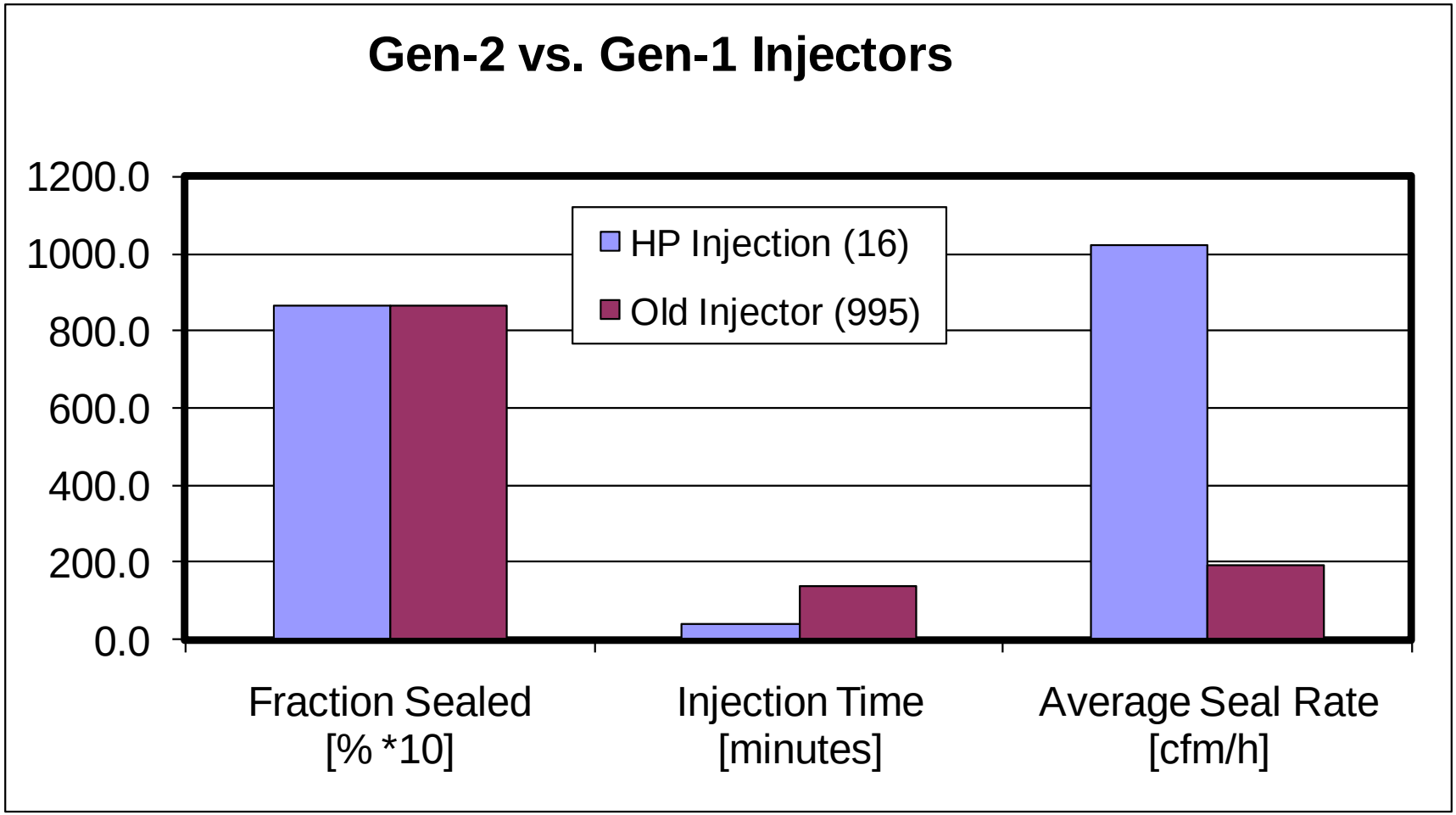
Residential Aerosol-Sealing Applications



Aerosol-Sealing Large Commercial Ducts

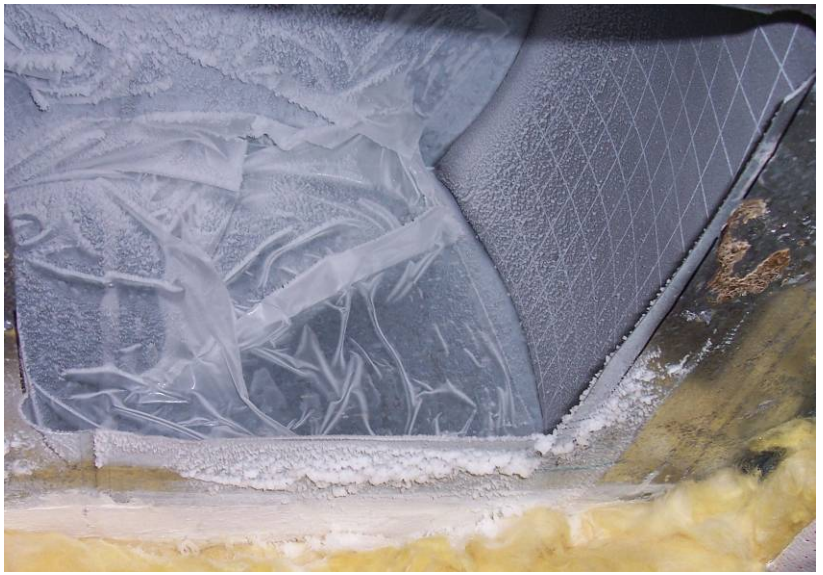
- **Blocking Diffusers**

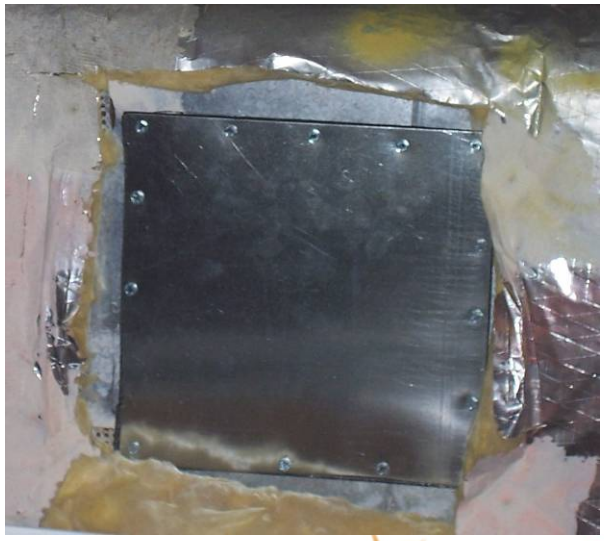
Aerosol-Sealing Large Commercial Ducts

- **Downstream of VAV boxes**

Aerosol-Sealing Large Commercial Ducts

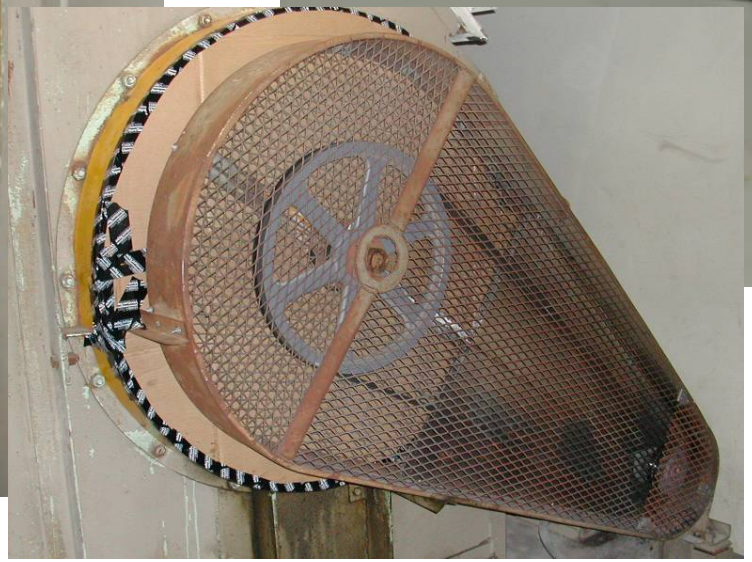
- **Downstream of VAV Boxes**

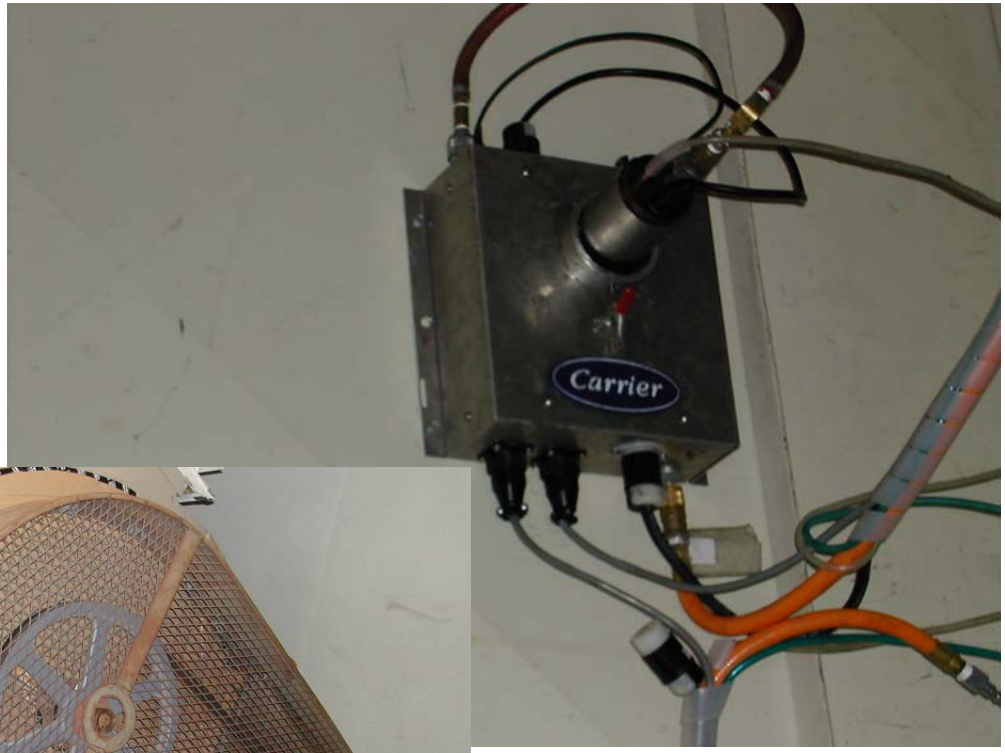




Aerosol-Sealing Large Commercial Ducts

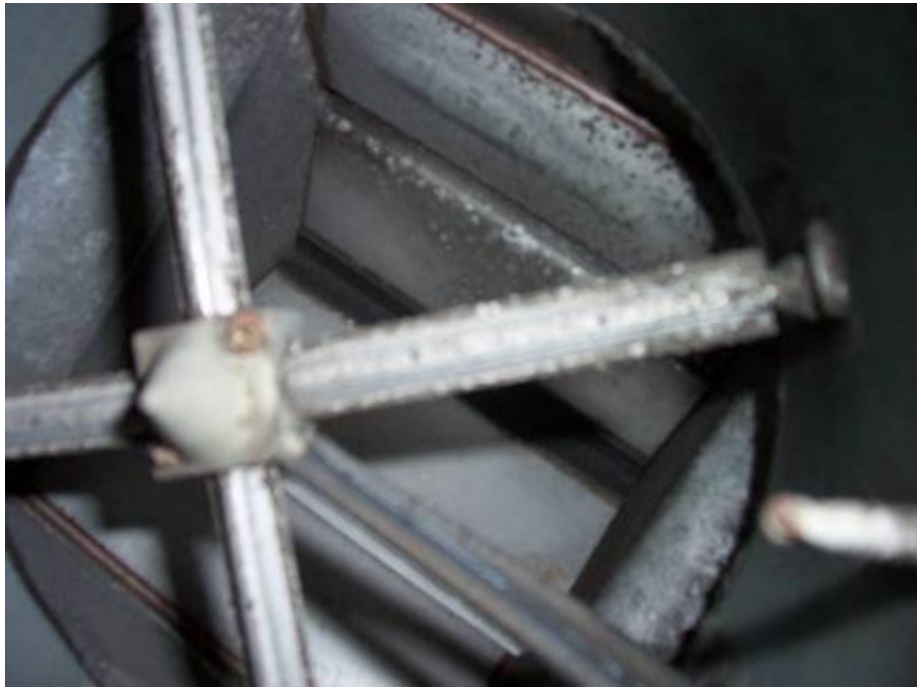
- **Sealing Through Main Supply Fan**





Aerosol-Sealing Large Commercial Ducts

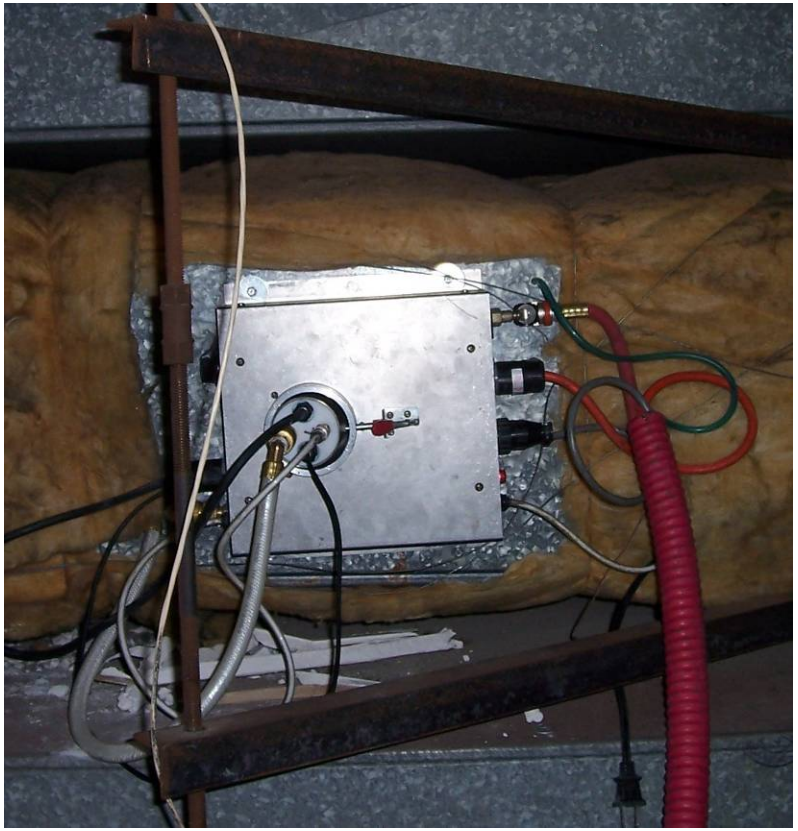
- **Sealing Through Pneumatic-Control Terminal Boxes**



Aerosol-Sealing Large Commercial Ducts

Aerosol-Sealing Large Commercial Ducts

- **Dual Deck Laboratory Supply Sealing**

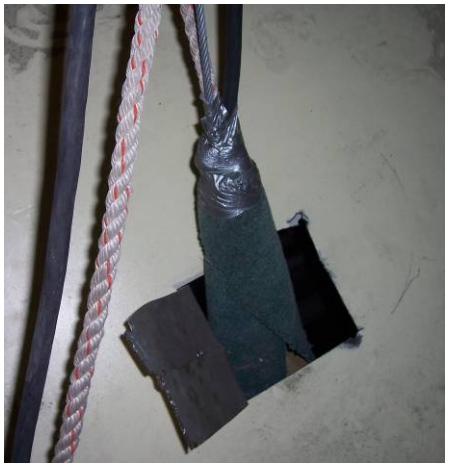


Aerosol-Sealing Large Commercial Ducts

- **Supply Shaft Sealing**

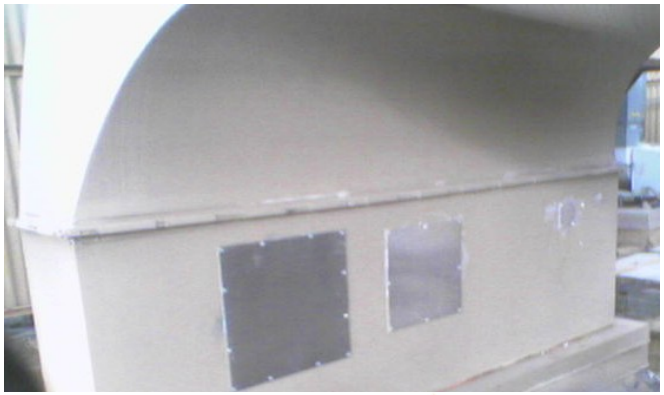
Aerosol-Sealing Large Commercial Ducts

- **Supply Shaft Sealing**



Aerosol-Sealing Large Commercial Ducts

- **Large Lab Exhaust Sealing**



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Aerosol-Sealing Multifamily Exhaust Ducts

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Aerosol-Sealing Large Commercial Ducts

System Type	Fan Flow [cfm]	Initial Leakage [%]	Fraction Sealed
Constant Volume Supply	69,000	19%	87%
Dual Duct Supply	93,000	36%	78%
CV Exhaust	22,000	27%	85%
CV Exhaust	20,000	20%	93%
Constant Volume Supply	14,000	19%	87%
VAV Supply	46,200	19%	92%
CV Exhaust	10,000	10%	90%
VAV Induction Supply	16,610	15%	92%
CV Supply/Exhaust	10,995	1% - 23%	87%
CV Exhaust	8,200	19%	85%
CV Exhaust	4,350	54-70%	75%
Constant Volume Supply	63,000	29%	89%
Supply/Return Risers	18,000	17%	91%
AVERAGE		**23%**	**87%**

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National Impacts of Duct Leakage

- **Residential Energy Savings Potential Estimate**
  - 50% of energy through ducts
  - 15% average savings
  - Estimated annual savings potential = 0.7 Quads = $10B

- **Commercial Energy Savings Potential Estimate**
  - 25% energy savings for ventilation
  - 10% average heating/cooling savings
  - Estimated annual savings potential = 0.7 Quads = $10B