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Commercial & Institutional HVAC Duct Leakage and Retrofit Duct Sealing

Conservation Applied R&D Grant

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Center for Energy and Environment

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- We conduct research and develop programs so that:
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  - Government agencies and nonprofits spend less on facilities and functions;
  - Utilities achieve their energy-efficiency goals at least-cost; and
  - Households save money and improve comfort.

What we do

- Program Design and Delivery
- Lending Center
- Engineering Services
- Public Policy
- Innovation Exchange

Acknowledgements

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Minnesota Department of Commerce
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mncee.org > Innovation Exchange > Projects
Saving Energy by Reducing Duct Leakage in Large Commercial & Institutional Buildings

http://www.mncee.org/Innovation-Exchange/Projects/Current/Saving-Energy-by-Reducing-Duct-Leakage-in-Large-Co/

Agenda

- C&I Duct leakage and associated energy penalties
- Minnesota Research Study
  - Measuring duct leakage
  - Measuring retrofit duct sealing efficacy
  - The cost of retrofit duct sealing
- Ongoing duct leakage pilot for cost effective opportunities

Duct Leakage

- Duct leakage is *any* airflow into or out of the duct system outside of the intended locations
  - Longitudinal seams, transverse joints, branch take offs, wall penetrations, damper shafts, fasteners, unplugged test ports, orphaned branches, etc.
  - It generally does *not* include equipment leakage, e.g. AHUs and VAV boxes
- Duct leakage requires airflow and a pressure drop
- Leakage fraction, f_L

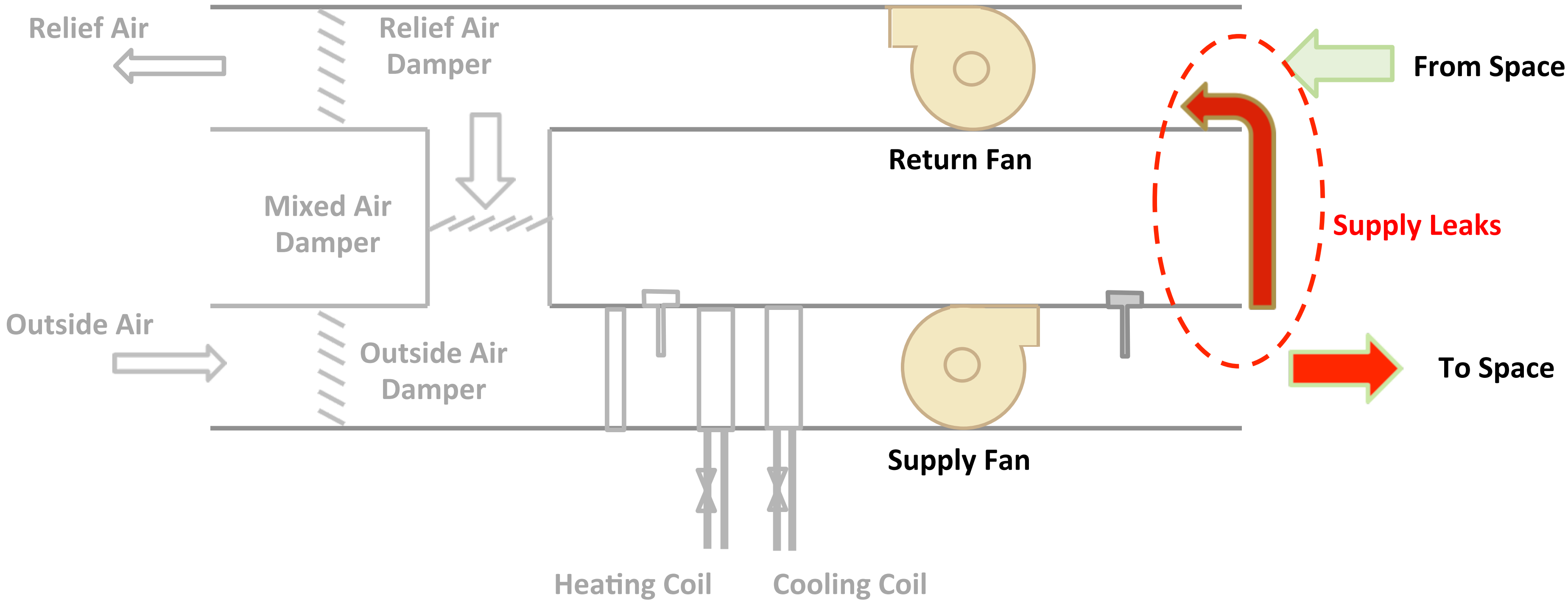
State of Sealing

Moderate standards & low attention

- Duct leakage has historically been considered an HVAC performance issue and not an energy efficiency issue
- Sealing codes and testing standards virtually unchanged until June 2015 (increased sealing requirements for low pressure systems)
- Leakage testing < 3" w.g. operating pressure not required

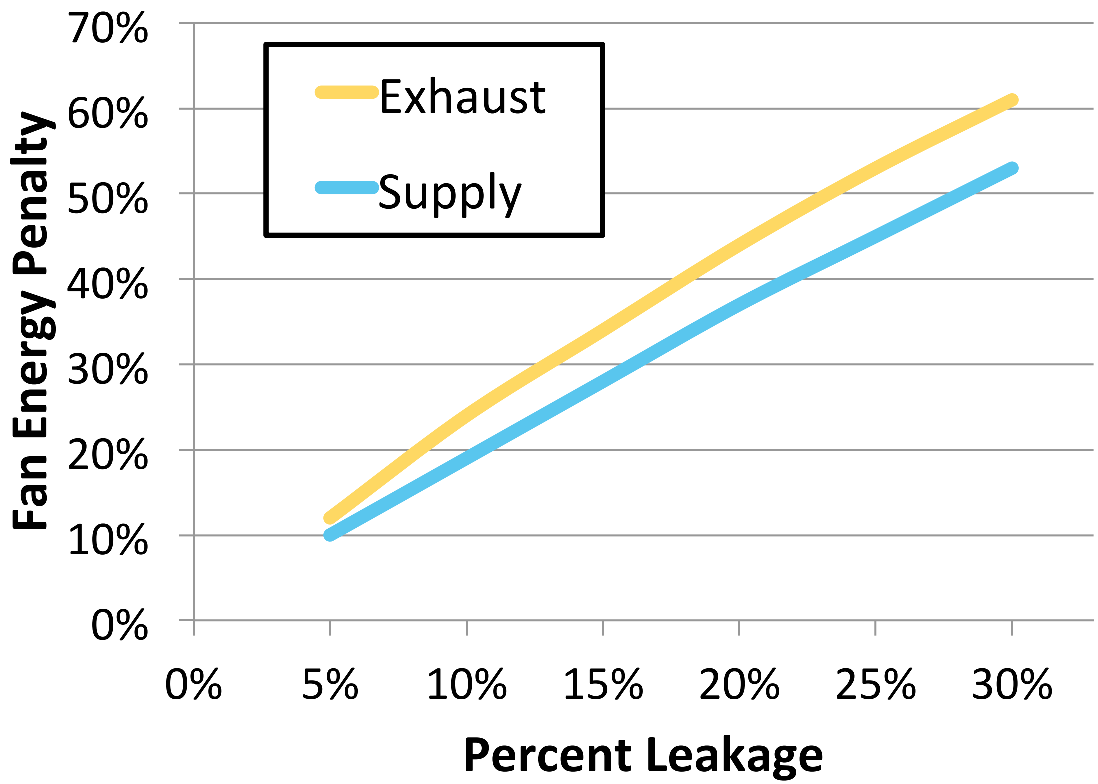
Nonetheless, prior work demonstrates real energy penalties & savings opportunities

Duct leakage increases fan energy use

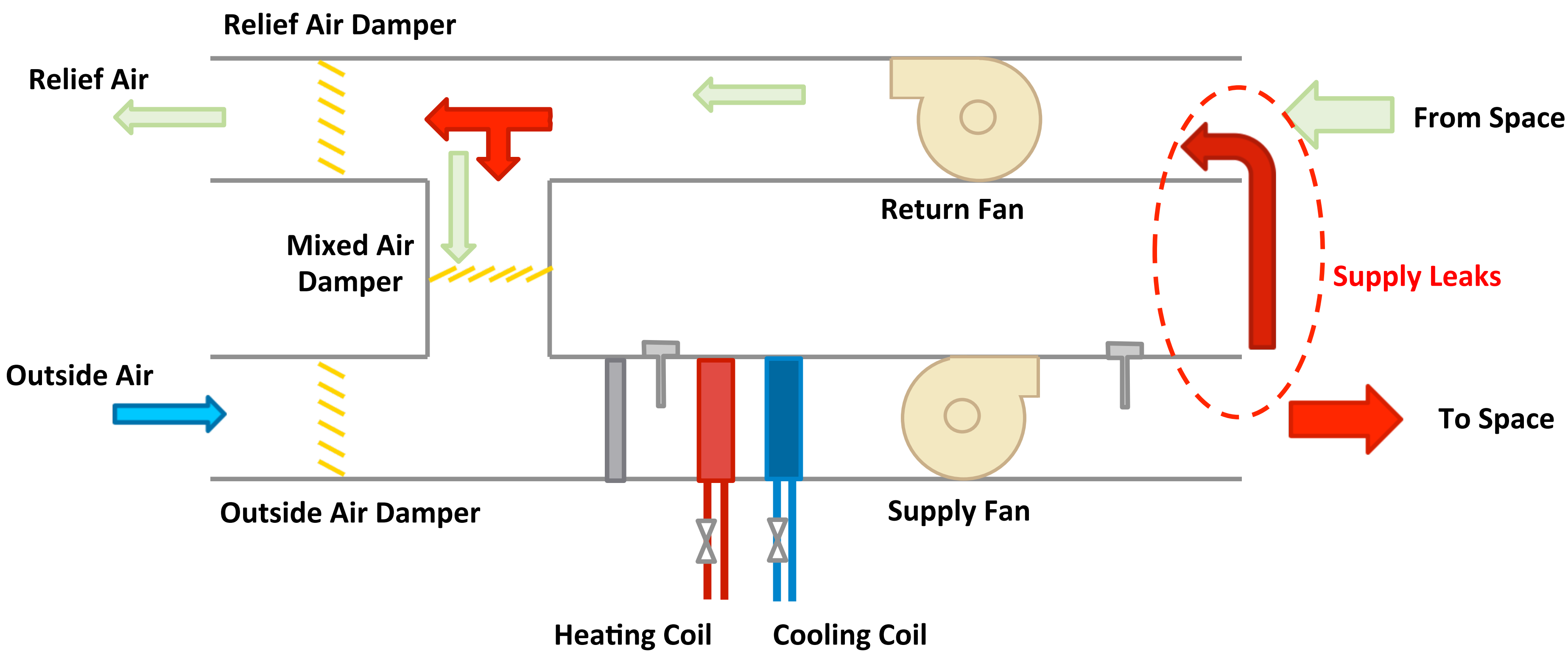


Fan Energy Penalty of Duct Leakage

- Supply: Fan power scales to leakage flow raised to power 2.4
- Exhausts: Fan power scales to leakage flow raised to power 3



Duct leakage increases space conditioning energy



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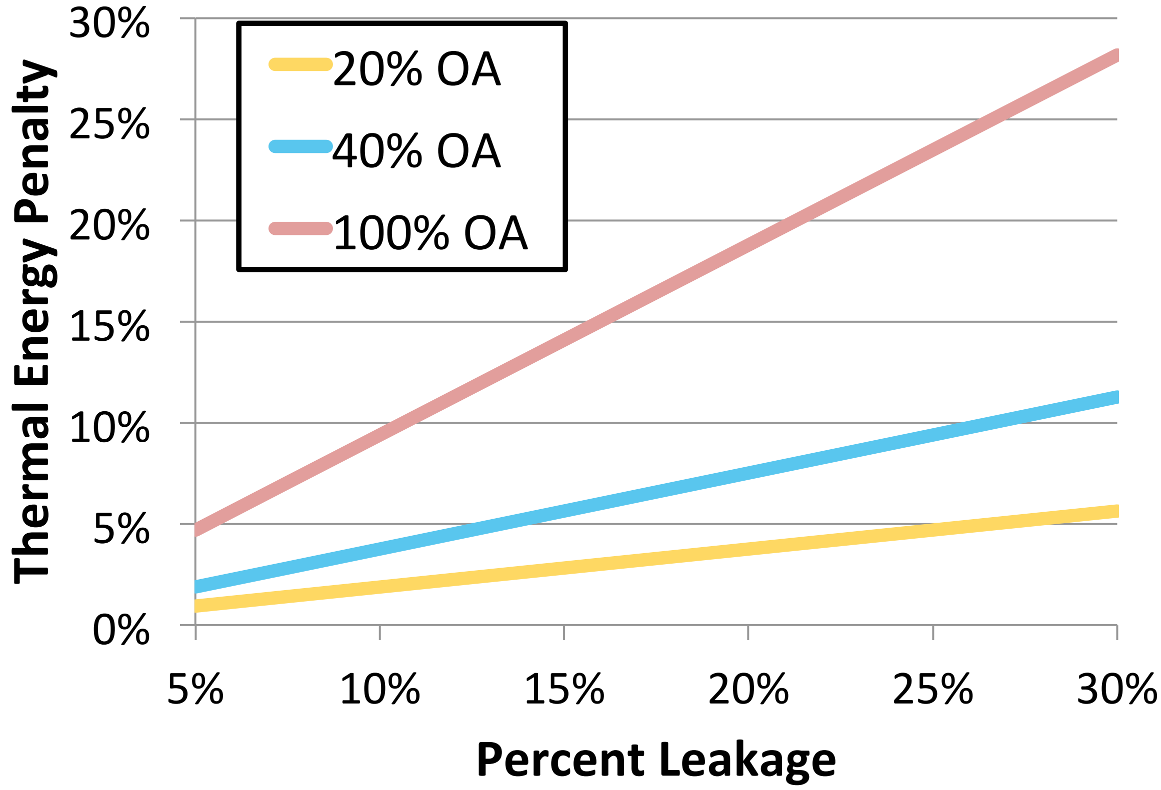
More Penalties from Duct Leakage

- Building specific
- Depends on OA and building pressure
- ~100% OA systems = exhausts



The fraction of leakage flow and resulting energy impacts can be substantial

- Wray et al. (2005) quantified the leakage flow fraction under normal operating conditions in 10 systems
  - Seven had leakage of 9% to 26% of flow (average 15.6%)
  - Three had leakage less than 5%
- Diamond et al. (2003) and Wray and Matson (2003) measured and modeled savings of 20 to 50% of fan energy in reducing leakage flow fraction from 20% to 5%
- Modera (2005, 2007) reduced the effective leakage area (ELA) of 10 duct systems by 69% to 93% using an aerosol sealant

Research Objectives

- Characterize the Design and Installation of C&I Duct Systems in Minnesota
- Quantify Duct Leakage and Associated Energy Impacts
- Seal Duct Leaks and Quantify Leakage Reduction
- Develop Procedures to identify cost effective retrofit opportunities

CARD Project

Duct Leakage in Large Commercial Buildings

Year Funded: 2013
Report Year: 2015
Sample Size:
- 63 systems screened
- 30 systems leakage tested
- 20 systems sealed

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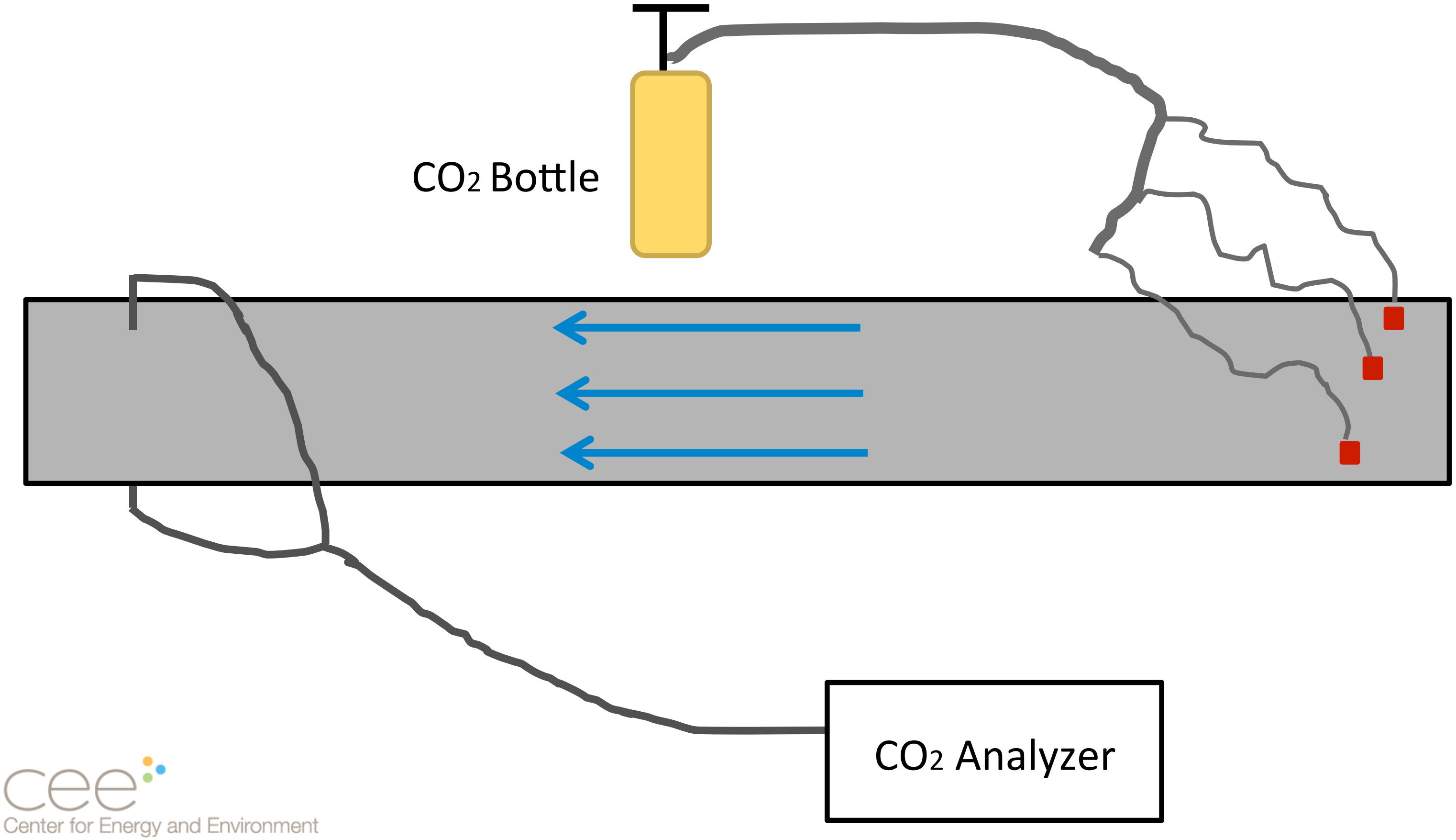
Measuring Duct Leakage

- Static Pressure Test
  - Block diffusers and use calibrated fan to measure flows over a range of duct pressures
  - Measure duct leakage at a reference pressure and compute leakage rate (leakage at normalized pressure)
- Tracer Gas & Powered Flow Hood Methods
  - Tracer gas to measure total system flow
  - Powered flow hoods to measure diffuser flow rates
- AFMS
- Pitot/Anemometer traverses

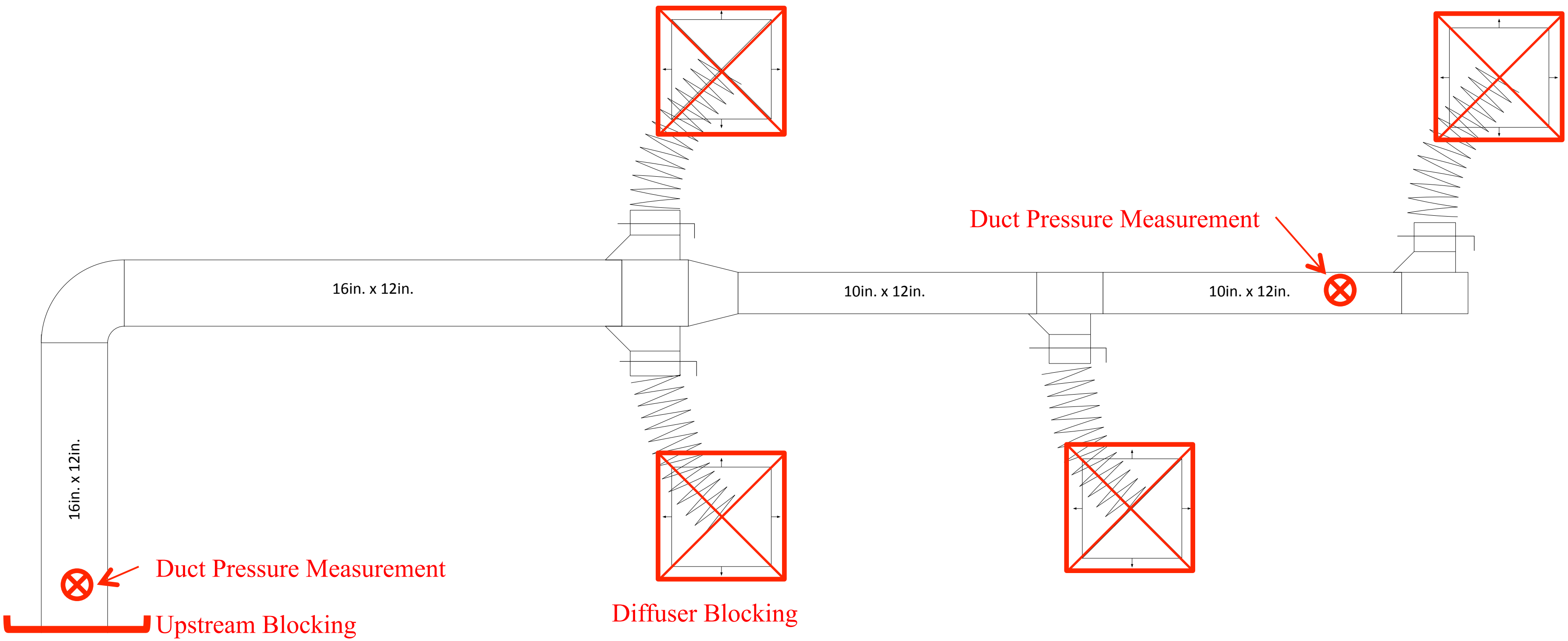
Tracer Gas & Flow Hood

- Upstream: Tracer Gas
  - Inject CO_2 into ducts
  - Measure CO_2 concentration downstream
  - Compute supply flow rate
- Downstream:
  - Another Tracer gas measurement OR
  - High-accuracy powered flow hood to measure diffuser flows
- The duct leakage is the difference in the upstream & downstream flow measurements ±3 %

Tracer gas testing




Static Pressure Testing



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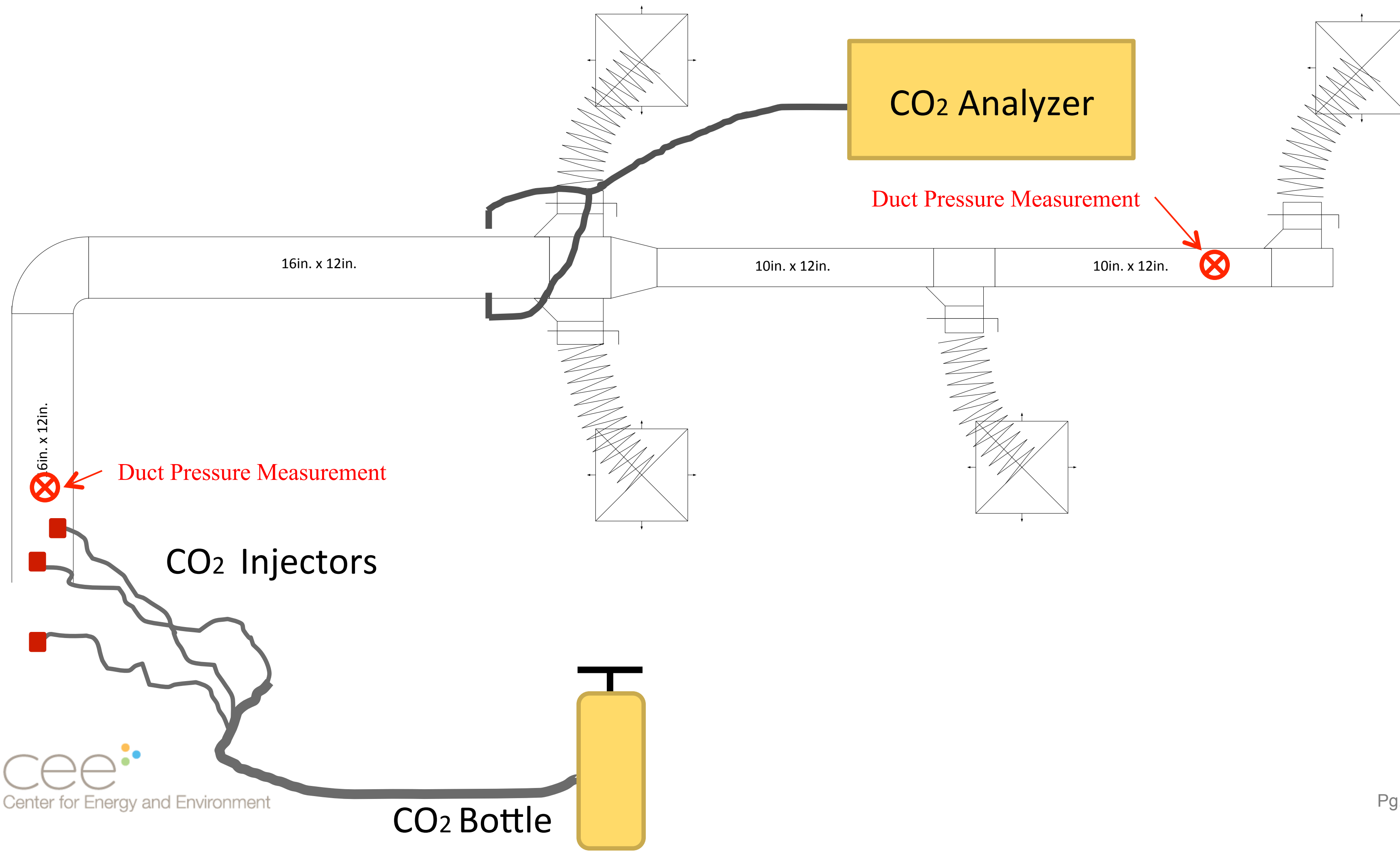
Tracer Gas Testing



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Quantifying C&I Duct Leakage in Minnesota

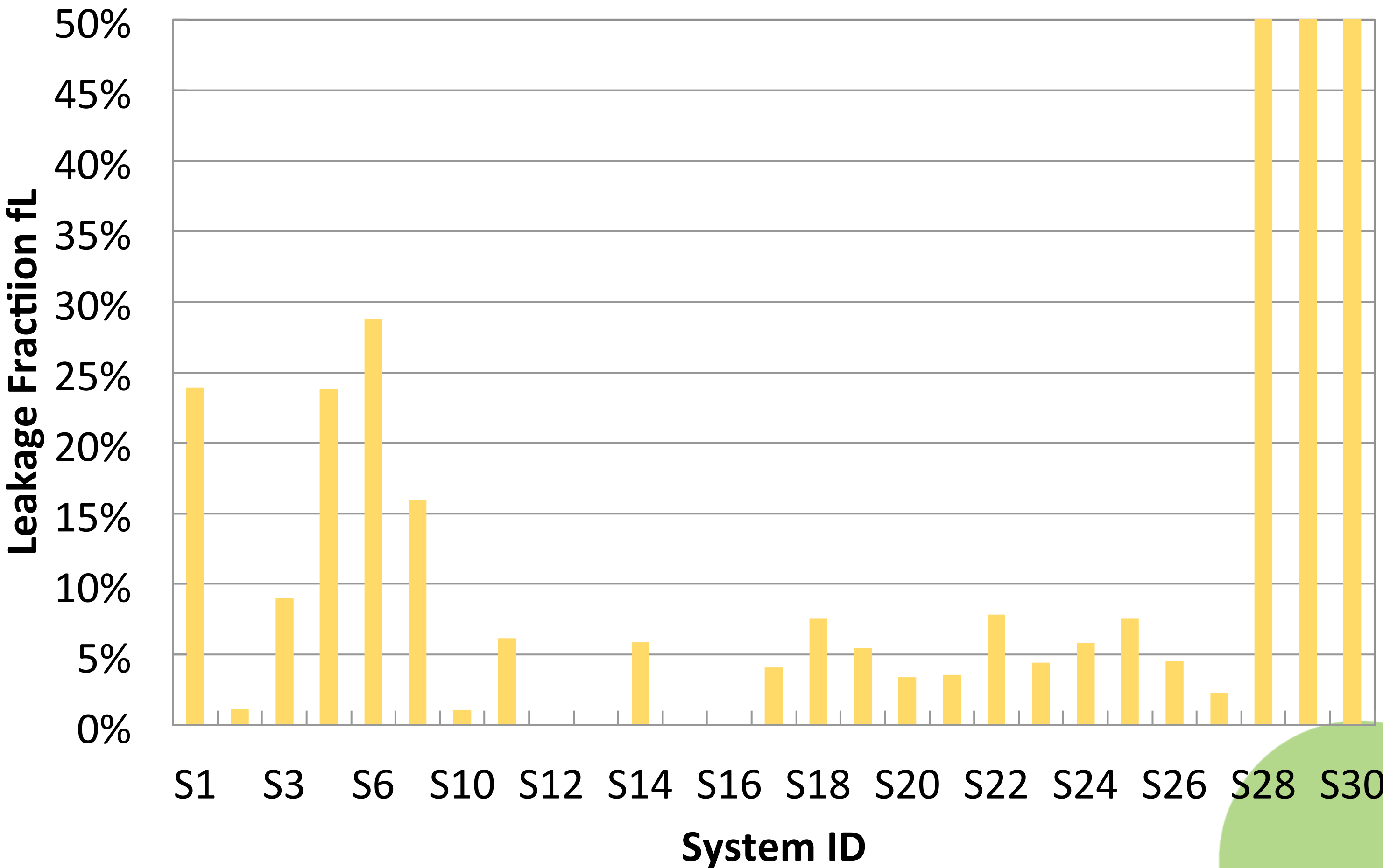
Screening Systems in Buildings:

- Screened 63 systems
- Ruled 30 out systems due to apparently tight ductwork, logistical issues, measurement issues, and very low savings estimates

Measured Leakage in 27 systems:

- Supply & exhaust systems between 500 and 28,000 design-cfm
- In buildings ranging from 27,000 to 900,000 SF
- Leakage fractions between 0% and 29% of measured flow rates
  - Average 8% duct leakage (median 5%)
  - Systems with prior sealing had duct leakage less than 2%
  - Duct leakage was 50% to 66% less than anticipated
- Three multi-family gypsum board exhaust systems had substantial leakage, between 55% and 80%

Duct Leakage Measurement Results



Key Take Aways

- Low and medium pressure ductwork in Minnesota is relatively tight
- Apparently tight (construction/existing sealing) duct systems are tight
- Owner/operator impressions of duct leakage do not predict measured duct leakage
- We no found correlation between system characteristics or operational details and leakage fraction
- About 15% of systems have excessive duct leakage (over 15%)

Sealing Industry Standard Methods

- Diverse product competition
- Non-aerosol technologies have additional application constraints

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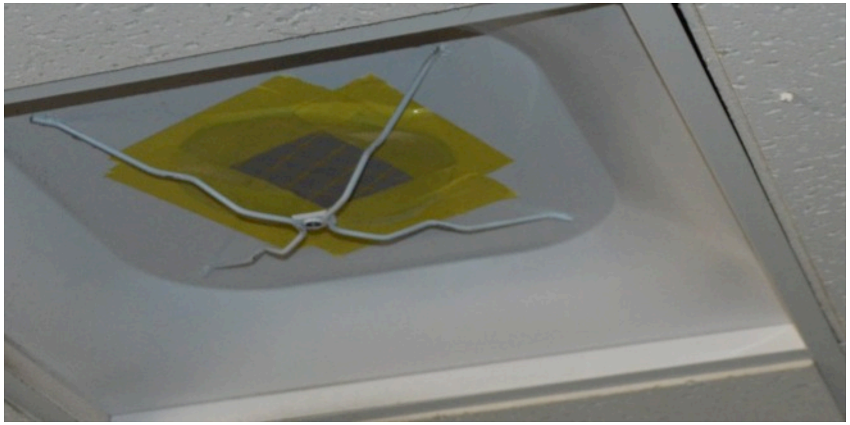
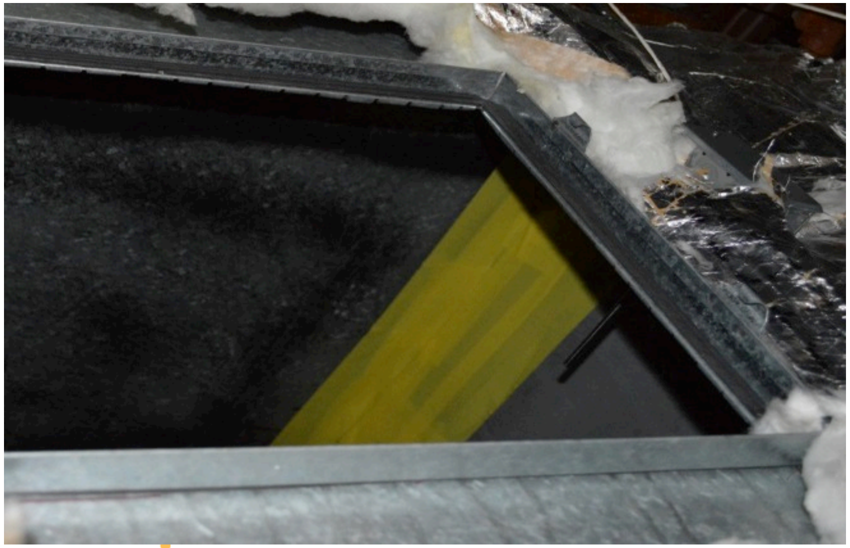
Traditional Measures

Traditional Results

Aeroseal Method





Aeroseal Results

Quantifying Retrofit Duct Sealing

Observed Sealing:

- 75% sealing success rate -- using both traditional & Aeroseal methods

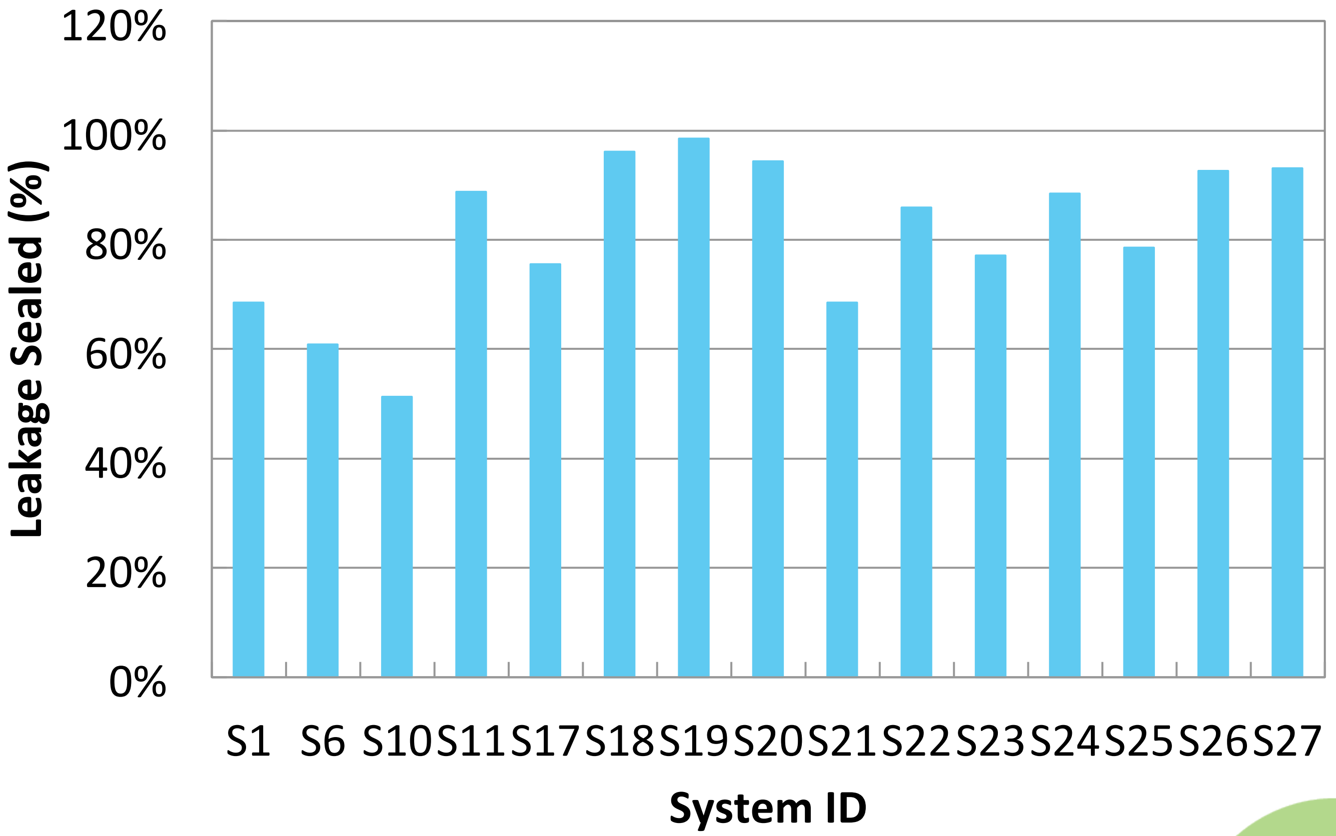
Leakage Reductions

- Between 53% and 98% of duct leakage was sealed (avg. 81%, med. 86%)

Characterization

- Unsuccessful sealing projects can be avoided in future work (e.g. large leakage paths in gypsum board exhausts, operationally challenged HVAC systems, initially sealed or tight systems)

Sealing Results



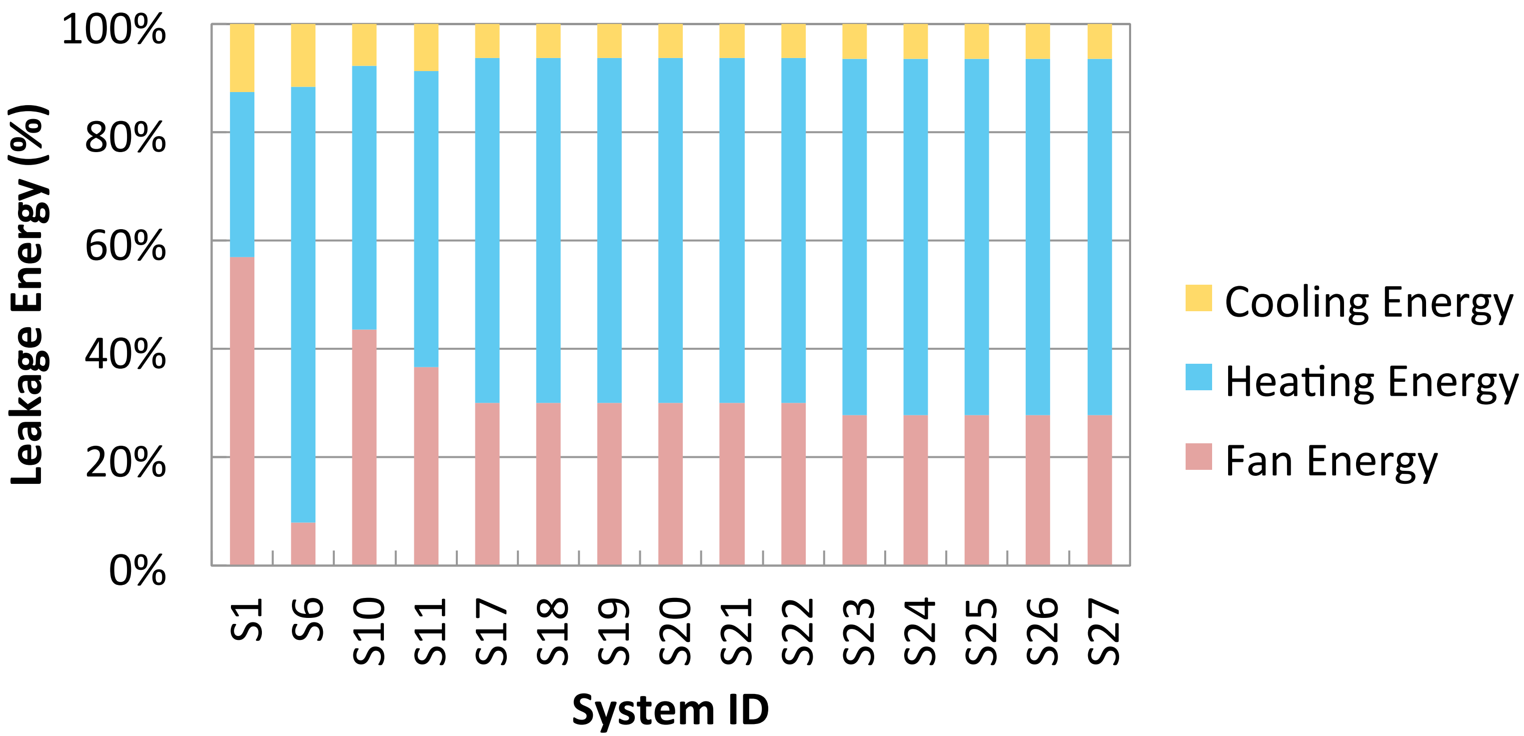
Retrofit Duct Sealing Costs

System Code	Contractor	Flow Type	Design Flow (cfm)	Sealing Cost	Cost per cfm-design	Cost per lineal ft	Cost per FTE-day	Cost per cfm-sealed
S1	C1	VAV	510	$983	$1.93	$11.30	$491	$6.68
S3, S4	C1	CAV	4,000	$3,950	$0.99	$6.41	$494	$22.58
S6	C2	VAV	2,000	$4,049	$2.02	$14.67	$831	$12.10
S10	C2	Exhaust	19,645	$5,050	$0.26	$23.38	$860	$53.89
S11	C2	Exhaust	28,215	$5,703	$0.22	$36.56	$800	$17.23
S17, S18	C2	CAV	23,395	$5,778	$0.22	$27.86	$730	$7.21
S19 - S22	C2	CAV	15,420	$7,752	$0.61	$13.37	$877	$13.05
S23	C2	CAV	19,525	$8,374	$0.39	$21.04	$817	$7.22
S24 - S27	C2	CAV	19,125	$8,890	$0.45	$7.79	$671	$15.25
S28, S29	C2	Exhaust	240	$5,703	$23.76	$5.43	-	$27.85
S30	C2	Exhaust	675	$4,151	$6.15	$10.62	$678	$27.16
		Mean	12,068	$5,489	$3.36	$16.22	$725	$19.11
		Median	15,420	$5,703	$0.61	$13.37	$765	$15.25

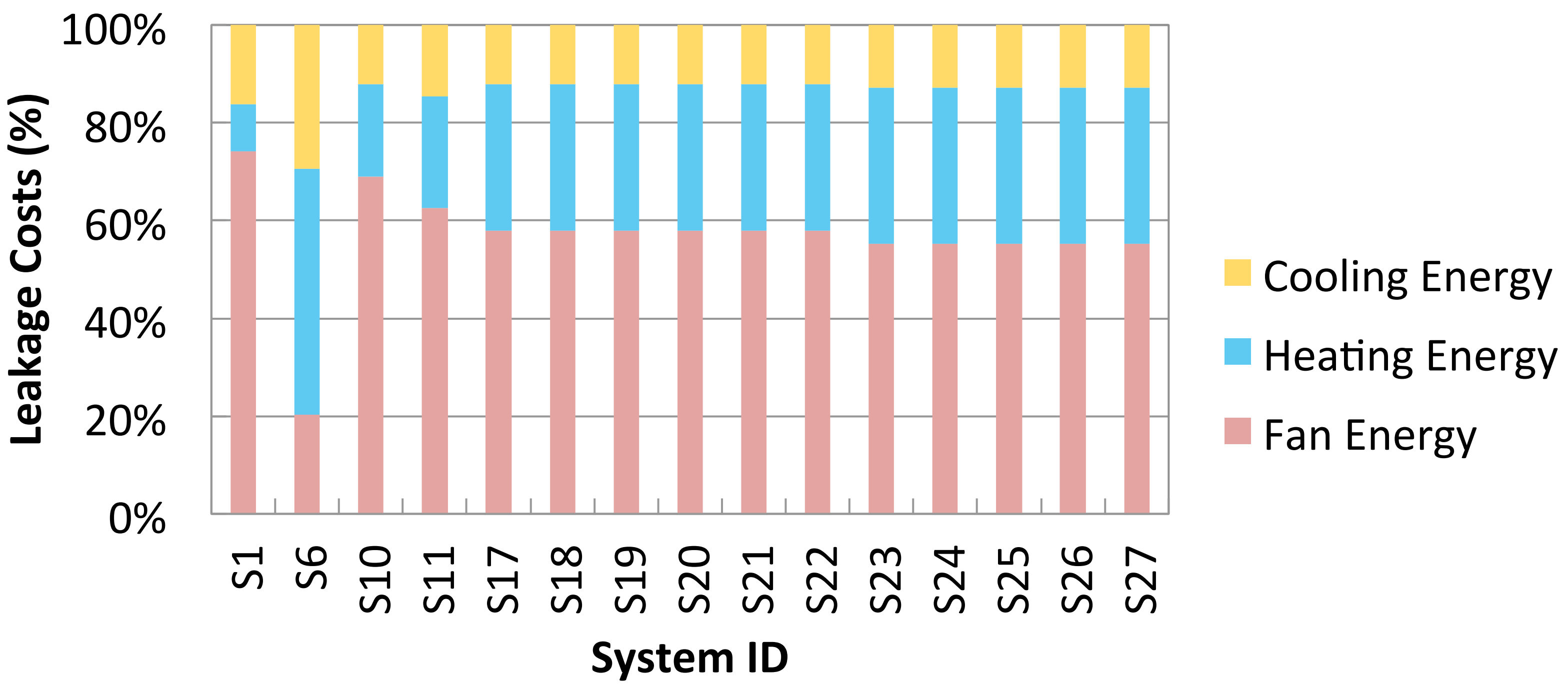
Key Retrofit Duct Sealing Take Aways

- Retrofit duct sealing works
  - Conventional methods and Aeroseal method
- Conventional methods were generally not a viable approach
  - Restricted duct access or external insulation
- Few constraints to the Aeroseal process
- Labor drives retrofit duct sealing costs
  - Blocking ducts for pressurization and sealant delivery
  - Measuring duct leakage costs nearly as much as sealing duct leakage
  - **Verification of sealed leakage is built into the process**

Energy Savings from Duct Sealing



Cost Savings from Duct Sealing



Payback vs Design Intent

- Paybacks range from 4 to 140 years

Pilot: Finding Cost Effective Retrofit Opportunities

- Systems with moderate to high leakage (cfm)
  - Avoid apparently tight or sealed systems
  - Operating pressure above 0.5 “ w.g.
  - Design flows greater than 4,000 cfm
- Systems that are relatively inexpensive to seal
  - Avoid complex duct systems
  - ~Less than one blocking per 300 cfm
- Systems with good savings potential
  - Supply ducts located in ceiling return plenum
  - Exhaust systems
  - Operate a large number of hours per year
  - Large fraction of outside air

Pilot Scope

PROJECT PAGE
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- Extends through 2016
- Develop case studies from 5 cost effective duct sealing retrofits
- Test preliminary screening criteria for cost-effectiveness
- Identify additional screening criteria
- Validate & improve static pressure based validation of sealing results

In Conclusion

- Duct Leakage can be a significant energy & operating cost issue
  - Extra fan power & heating and cooling energy
- Duct sealing works
  - Existing sealed ducts are ***tight***
  - Traditional & Aeroseal retrofit duct sealing ***works***
  - Aeroseal expands opportunities via fewer duct access requirements
- Energy penalties are from ***heating*** (natural gas)
- Cost penalties are from fan ***cooling & fan power*** (electrical)
- Cost-effective sealing depends on system attributes: ***size, pressure, complexity & existing sealing***

THANK you!

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