Impact of Commercial Building Infiltration on Heating and Cooling Loads in U.S. Office Buildings

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ABSTRACT

With the exception of a few analyses of the impacts of ASHRAE Standard 62-89 and energy use in specific buildings, the energy use in commercial building due to infiltration and ventilation flows has received little attention. However, as improvements have been made in insulation, windows, etc., the relative importance of these airflows has increased. Previous work at NIST described a research plan to quantify, and assess opportunities to reduce, the energy and indoor air quality impacts of building airtightness and ventilation system control in office buildings (Emmerich et al. 1995). It included an initial estimate that infiltration is responsible for 18% of the total heating energy use and 2% of the total cooling energy use in US office buildings but also concluded that an improved estimate would require the development of a new simulation tool coupling a multizone airflow model with a building thermal analysis program.

McDowell et al. (2003) describes the incorporation of the AIRNET airflow model (the airflow simulation portion of the CONTAMW multizone IAQ modeling program) into the TRNSYS energy simulation program to be the needed tool. The resulting integrated simulation tool was then used to estimate the energy usage of 25 buildings representing the U.S. office building stock over a range of infiltration and ventilation conditions. This paper presents detailed simulation results including infiltration rates and their associated heating and cooling loads with an emphasis on the results from the buildings representing recent construction.

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Objective

Analyze energy liabilities of U.S. office building **infiltration** and ventilation.

Demonstrate combining separate network airflow and building energy modeling programs

Background

- Previous research has shown modern office buildings to be leakier than often assumed.
  - Update on U.S. data at AIVC 2005
- Energy liabilities of air leakage and ventilation not known – very little study
  - Often infiltration is assumed to be negligible.
  - Lack of requirements in U.S. for whole building airtightness or CABs, e.g., ASHRAE Standard 90.1
- Airflow modeling capabilities make calculation of these energy impacts possible.

Method

- Combined network airflow model (CONTAM) with building energy model (TRNSYS)
- Statistically representative office building set used to make national estimate
- Calculated annual heating and cooling loads – no equipment models used

Model Integration

- CONTAM airflow solver incorporated as a TRNSYS type
- CONTAM GUI used to create airflow models
- Annual simulations with iteration between airflow and thermal types at each 1 hour time step

PNL Building Set

- Set of 25 buildings defined through cluster analysis to represent U.S. office building stock (through 1995)
- PNL definitions include thermal properties, internal loads, setpoint schedules, etc.
- Size range: 1 to 45 floors, 6,200 to 2,480,000 ft^2 (576 to 230,399 m^2)
- Located in cities throughout the US

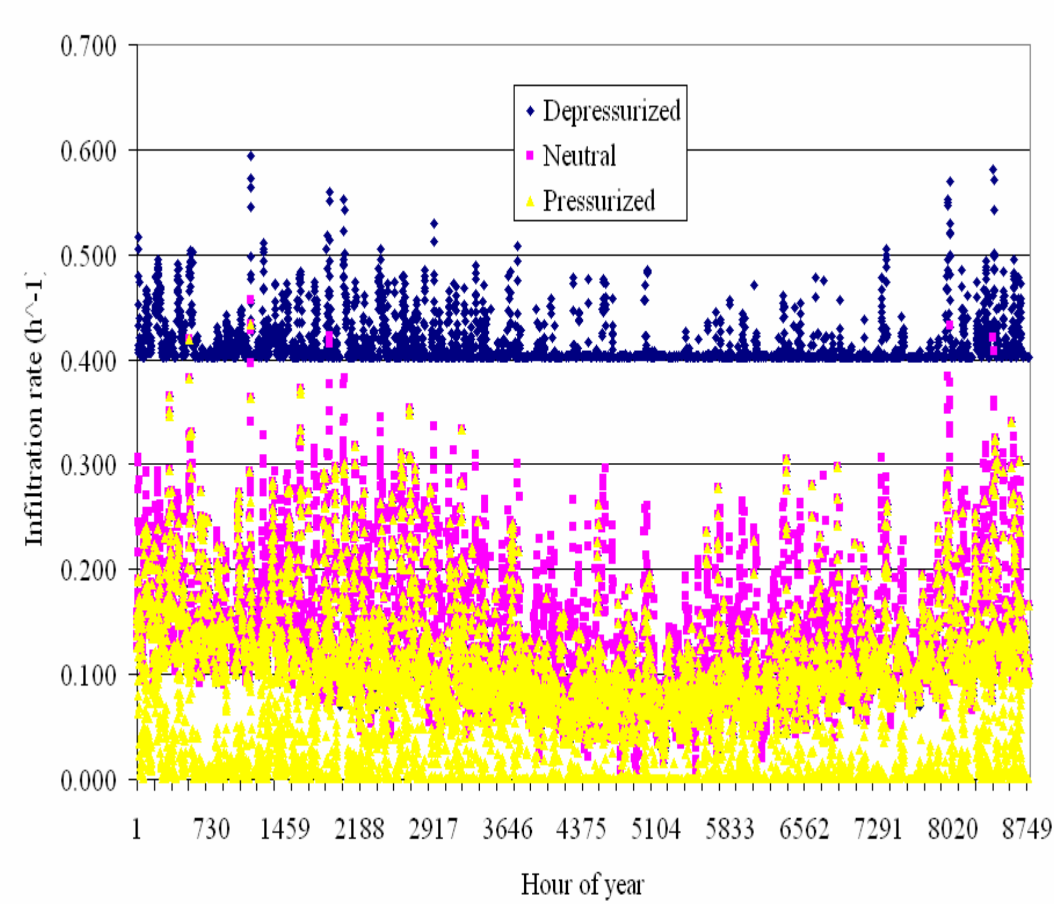
Bldg. No.	Floor Area (m^2)	No. of Floors	Year Built	Location	Floor Area Represented (10^6 m^2)	Envelope Leakage (cm^2/m^2)
1	576	1	1939	Indianapolis, IN	15.6	15
2	604	3	1920	Cleveland, OH	24.8	15
3	743	1	1954	El Paso, TX	21.5	10
4	929	2	1970	Washington, DC	26.5	7.5
5	1486	2	1969	Madison, WI	51.7	5
6	2044	2	1953	Lake Charles, LA	31	10
7	2601	4	1925	Des Moines, IA	68.2	10
8	3716	5	1908	St. Louis, MO	28.3	10
9	3902	2	1967	Las Vegas, NV	43.2	7.5
10	4273	3	1967	Salt Lake City, UT	35.5	5
11	13935	6	1968	Cheyenne, WY	28.6	5
12	16722	6	1918	Portland, OR	27.9	10
13	26941	11	1929	Pittsburgh, PA	58.5	10
14	26941	6	1948	Amarillo, TX	37.3	10
15	27870	12	1966	Raleigh, NC	32.7	5
16	28799	10	1964	Dallas, TX	22.9	5
17	53882	19	1965	Minneapolis, MN	27.6	3.33
18	67817	10	1957	Boston, MA	16.3	5
19	68746	28	1967	New York, NY	43.4	3.33
20	230392	45	1971	Los Angeles, CA	40.8	3.33
21	1022	2	1986	Raleigh, NC	117	5
22	1208	2	1986	Phoenix, AZ	92.2	5
23	1579	2	1986	Pittsburgh, PA	101	5
24	38089	9	1986	Pittsburgh, PA	64.5	3.33
25	46450	14	1986	Charleston, SC	54	3.33

Airflow Modeling with CONTAM

- Distributed envelope leakage based on available data (with engineering judgement) ranging from 3.3 to 15 cm^2/m^2 at 10 Pa
- Assumed ventilation rate of 5 L/s per person
- Performed simulations with balanced ventilation flows, pressurized and depressurized
- Included perimeter and core zones, elevator and stair shafts, plenums, and interzonal leakage due to doors, etc.

Results – Infiltration rates

- Predicted annual average infiltration rates range from 0.025 h^{-1} to 0.74 h^{-1} depending on ELA, climate, HVAC system flows, etc.



Hourly infiltration rates for Building 23 (2 story office in Pennsylvania)

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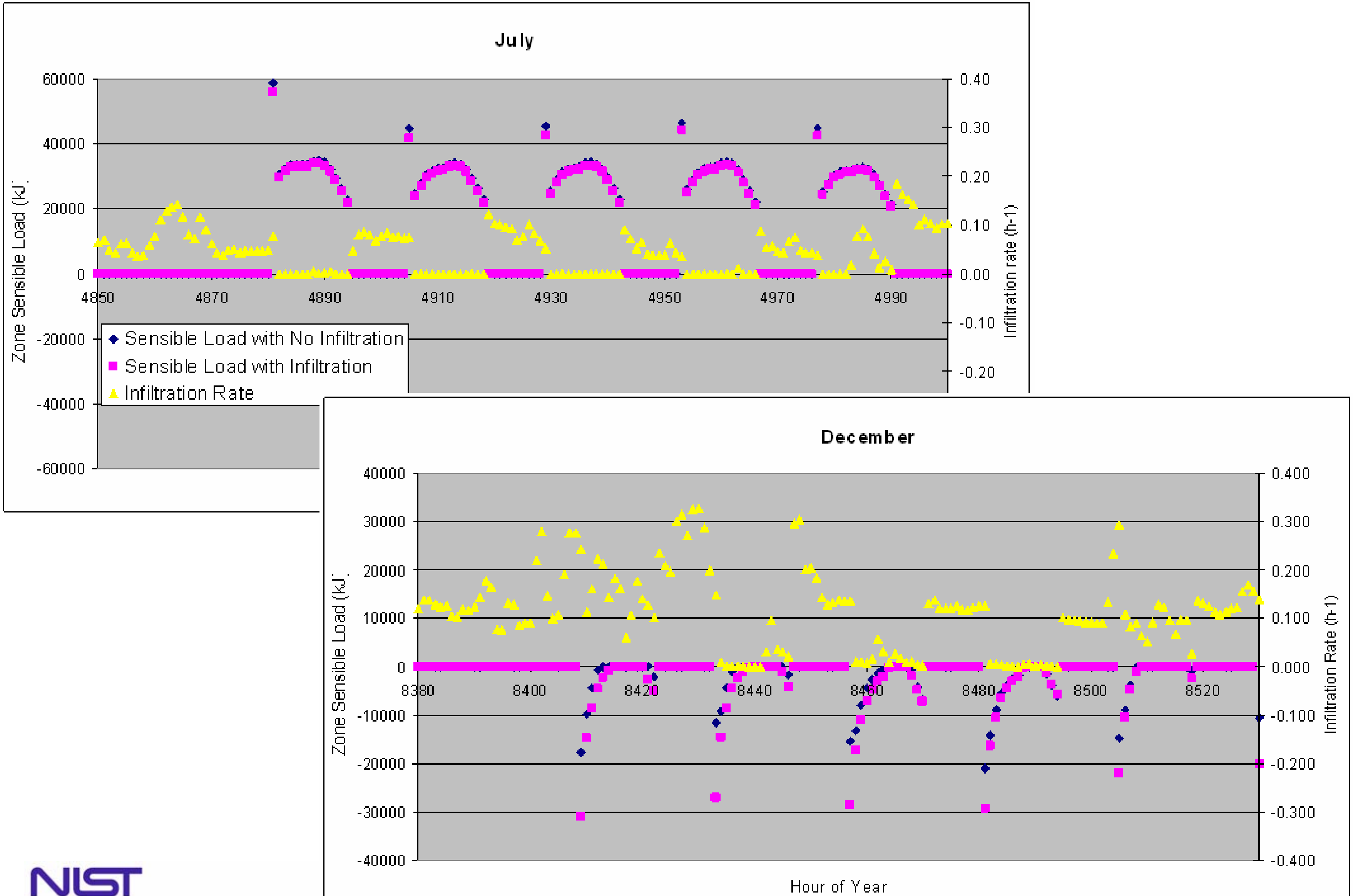
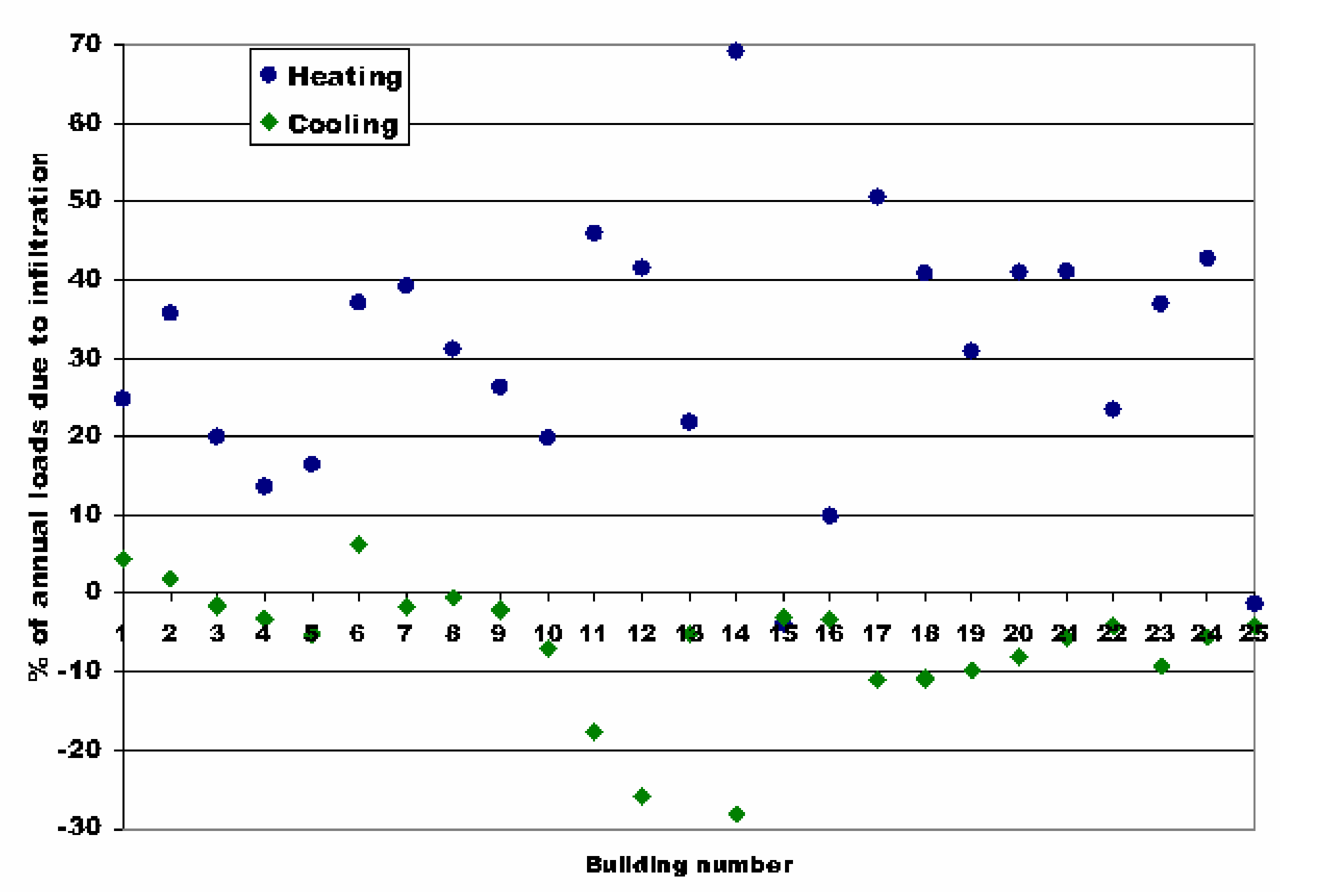
Results – example weeks in Penn.



Annual loads due to infiltration



- Average impact is 33 % of heating load
- Average impact is 5 % ***reduction*** of cooling load

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Discussion

- Infiltration is significant portion of U.S. office building heating load at typical envelope tightness
- Demonstrated possibilities in modeling energy and airflow using TRNSYS and CONTAM combination
- Limitations on accuracy include limited envelope leakage and ventilation system control data and lack of equipment modeling in this study
- Need to complete evaluation of economizer impact