Title
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Author
Modera, M.P.

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M.P. Modera

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Final Report:

Residential Air Leakage Database Compilation

Mark P. Modera
Applied Science Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

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Background

Under contract to the Department of the Army, the Energy Performance of Buildings Group at Lawrence Berkeley Laboratory has compiled a database of residential air leakage measurements. The primary objective of this contract was to compile a readily available sample of the air leakage measurements being performed in North America. The secondary objective was to compile building characteristics and climate data associated with each measurement.

Data Format

According to the contract, the data was to be compiled on a microcomputer operating under the CP/M operating system. For this reason, dBASE II was chosen as the management program for the data. This choice of program placed certain constraints on the structure of the database. Because of the manner in which data is accessed by dBASE II, putting all of the data into a single database file was impractical. The data was therefore placed in four separate databases which can be cross-referenced. The databases are: Leakage, Leakage Characteristics, House Characteristics, and Zipcode. The contents of these databases are summarized in Appendix I.

The databases are cross-referenced with an identification number for each house, a number for each leakage test on that house, and the zipcodes for all houses. The house identification numbers contain five digits starting with 10000 and are unique. The test numbers contain two digits, and are not unique. The zipcodes are used to relate climate data in the zipcode database to each house. Zipcodes do not uniquely specify any measurement or house.

Each measurement of house leakage appears in two unique database records, one in the Leakage database, and one in the Leakage Characteristics database. Both database records contain the house identification number, the test number, and the zipcode in which the house is located. The House Characteristics database, which contains a description of the house, can be accessed from either of the leakage databases via the house identification number. The Zipcode database, which contains a description of the climate, can be accessed via the zipcode. The zipcodes are included in the leakage databases so as to allow cross-referencing to climate without having to pass through the House Characteristics database.

Leakage Database

The Leakage database contains an abbreviated description of the results of each leakage measurement (see Appendix I). The purpose of this database is to allow for quick access of leakage information for a large number of houses. In addition to the three fields used to identify the house, the test and the climate, the Leakage database contains four fields of reduced leakage information. The leakage-information fields include: the average leakage area, the average flow exponent, the average specific leakage area, and the average flow at 100 Pa. These entries are averages of pressurization and depressurization test results (except for single-flow-direction tests). The Leakage database contains four

additional fields upon which the leakage information can be sorted.

The additional sorting fields allow certain subsets of the data to be analyzed independently. The first of these fields, the Measurement Rating, allows data with different levels of uncertainty to be separated. The Date of Measurement fields allow the data to be separated based upon the day, month, or year of the test. Sorting the data by the month of the measurement allows for examination of seasonal trends in air leakage. The House Condition fields allow the data to be corrected for anomalous conditions during the tests, such as sealed vents or chimney dampers. The Data Indicator fields serve two purposes. The First Test field is used to assure that a particular house does not appear more than once in a given analysis of the data, as some houses have more than one leakage measurement. The Post Retrofit field allows data to be separated based upon whether or not the house had been retrofitted, or been tested with the air distribution (duct) system sealed. Thus, there are six possible Data Indicator combinations for a given leakage measurement: 1) first test before retrofit, 2) additional test before retrofit, 3) first test after retrofit, 4) additional test after retrofit, 5) first test with ducts sealed, and 6) additional test with ducts sealed.

Leakage Characteristics Database

The Leakage Characteristics database contains a more complete description of the leakage measurement data and the conditions of the house during the measurements (see Appendix I). Similar to the Leakage database, the Leakage Characteristics database contains three fields which identify the house, the test, and the climate of the location (zipcode). It contains thirteen fields describing the leakage measurements and analysis. The leakage information includes the flow exponents, flow coefficients, regression correlation coefficients, leakage areas, and air changes at 50 Pa, for both pressurization and depressurization tests. Also included are the test standard used for the measurements, the regression weighting used for the analysis, and the Canadian leakage area*. Two other fields related to the measurements are: 1) one which describes what kind of organization made the measurements, 2) one which contains any reference in the literature to the measurements.

Eight additional fields describe the conditions during the measurements. Three of these fields describe the weather conditions: the windspeed, the outdoor temperature, and the indoor temperature. The remaining five fields describe the condition of the house, four of these fields containing a yes (Y), no (N), or unspecified (U) pertaining to the specified condition. The four conditions with their own fields are: 1) house doctored, 2) weather stripped, 3) caulked, and 4) modified windows. The fifth field contains a code letter for other house conditions. The complete code for these conditions is contained in Appendix I.

* The Canadian leakage area differs from the U.S. leakage area in that it is defined at 10 Pa rather than 4 Pa, and that the quoted area includes an assumed orifice-discharge coefficient.

Similar to the Leakage database, the Leakage Characteristics database also contains the Measurement Rating. This rating of confidence in the test results depends upon several factors: 1) whether or not the measurements were made according to an established standard (or done by a group with a reputation for precision measurements) 2) the windspeed during the test, 3) how many different data points were measured, 4) the calibration of the measurement equipment, and 5) the completeness of the description of the house condition during the test.

House Characteristics Database

The House Characteristics database provides an encoded description of the house, as well as a dated history of modifications made to the house (see Appendix I). The house is identified by the identification number used in the leakage databases. The location of the house is specified by three fields containing the zipcode, city, and state.

The house type is specified by five fields containing: the number of stories, the floor type, the roof type, the wall type, and the building type. The building type basicly describes the relationship between this house and other houses (i.e., detached, duplex or townhouse). Another five fields describe the HVAC system of the house, including 1) the number of fireplaces, 2) the number of fireplace dampers, 3) the existence of a central furnace, 4) the existence of a forced-air distribution system, and 5) the existence of ducts passing through unconditioned spaces. Also included are a year-of-construction field, two floor-area fields (conditioned, unconditioned), and conditioned-house-volume field.

Four additional fields contain the parameters required to determine the natural infiltration rate of the house (excluding leakage area) with the Lawrence Berkeley Laboratory infiltration model. These fields contain the height above grade, the shielding class (wind microclimate), the terrain class (wind macroclimate), and any references to tracer gas measurements made on the house.

Zipcode Database

The Zipcode database contains infiltration-climate descriptions. The climate in which a particular house is located is accessed via the zipcode - all databases contain a zipcode field. The Zipcode database also contains several other location indicator fields: city, state, and census region (see Appendix I).

The climate associated with each zipcode is characterized by two basic parameters, specific infiltration, and infiltration degree days. The specific infiltration is the infiltration rate for a typical house normalized for leakage area. In other words, it is the infiltration rate [m^3/h] per unit leakage area [cm^2], and depends on coincident indoor-outdoor temperature difference and windspeed. The typical house upon which specific infiltration is based has a uniform distribution of leakage area, is one story high, has a terrain class of 3, and has a shielding class of 3. The total annual specific infiltration is the average specific infiltration over a year. Infiltration degree days depend upon both specific infiltration and indoor outdoor temperature difference. They are analogous to conventional degree days, differing

in that they are degree-hours weighted by the instantaneous specific infiltration rate divided by 24.

The Zipcode database includes fields that could be used for a more detailed breakdown of the infiltration climate. This includes separation of wind and stack effect, and summer and winter seasons. At present, these fields are left blank — the climate is described simply by the total annual specific infiltration and the total infiltration degree days.

Database Contents

The structures of the databases delivered as the final product of this contract are presented in Appendix II. This appendix shows that the database contains 1100 fan-pressurization tests, presented in Leakage and Leakage Characteristics databases. The House Characteristics database contains data on 752 houses, located in the 111 different zipcodes contained in the Zipcode database.

The database contains 452 American houses and 300 Canadian houses. Of the American houses, approximately 130 are located in the Pacific Northwest, and approximately 160 are located in California. The remainder of the houses are distributed throughout the United States. The cities for which the database contains houses are shown in Figure 1.

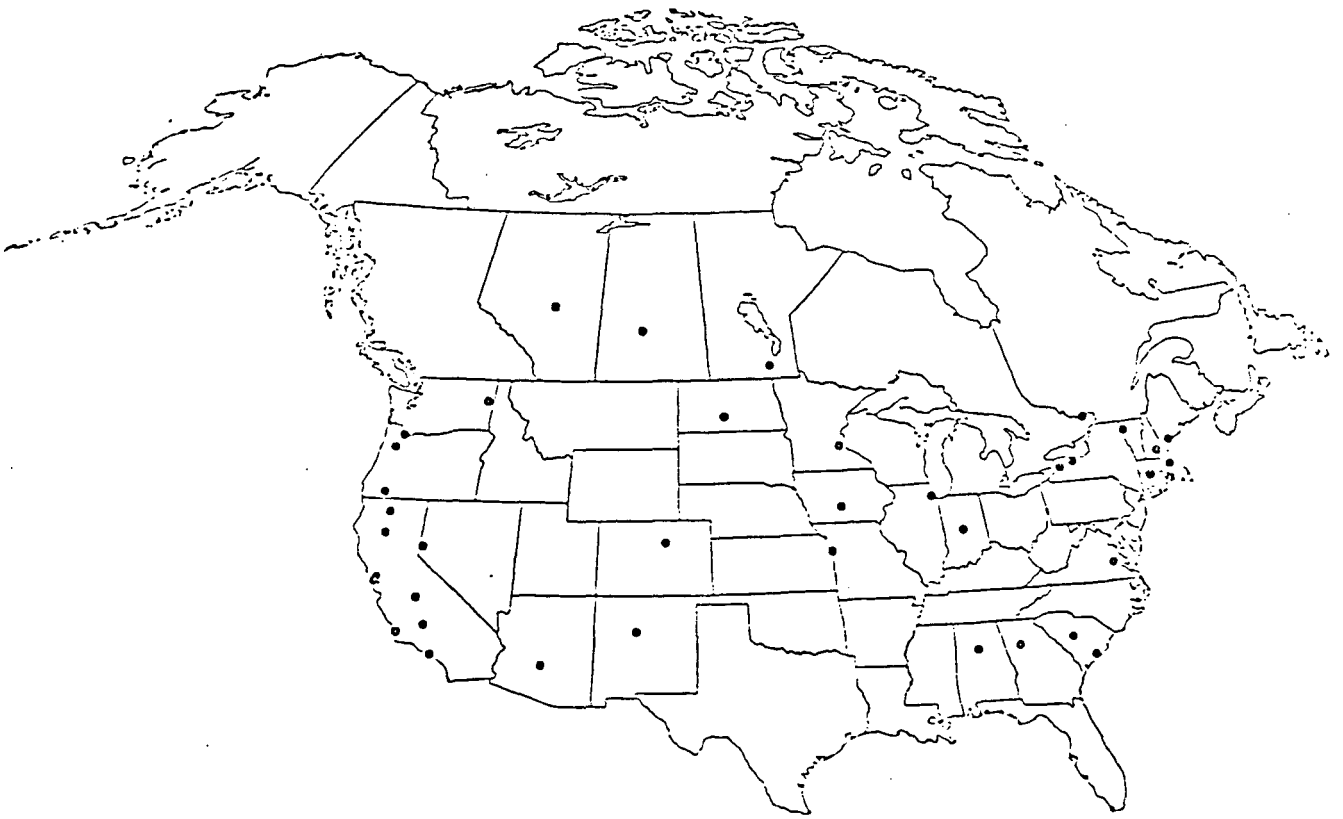

Figure 1: Cities in North America for which the database contains measurements of air leakage.

APPENDIX I

FILES

I. LEAKAGE DATABASES

(a) Leakage
(b) Leakage Characteristics

II. HOUSE CHARACTERISTICS

III. ZIPCODE

I. LEAKAGE DATABASES

(a) Leakage

1. House ID (alpha, 5)
2. Test Number (alpha, 2)
3. Zip Code (alpha, 6)
4. Average Leakage Area [cm^2] (num, 4)
5. Average Flow Exponent (num, 1.2)
6. Specific Leakage Area [cm^2/m^2] (num, 2.1)
7. Average Flow at 100 Pa [m^3/h] (num, 5)
8. Measurement Rating (1-5) (alpha, 1)

   1 = Best
   2 = Better
   3 = OK
   4 = Not Good
   5 = Terrible

9. Date of Measurement

Day	(alpha, 2)
Month	(alpha, 2)
Year	(alpha, 2)

10. House Condition

    Number of sealed vents (def.=9) (num, 1)
    Number of closed dampers (def.=9) (num, 1)

11. Data Indicator

    First Test (y/n/u) (alpha, 1)
    Post Retrofit (y/n/d/u) (alpha, 1)

(b) Leakage Characteristics

1. House ID (alpha, 5)

2. Test Number (alpha, 2)

3. Zip Code (alpha, 6)

4. Coefficient [m^3/Pa^n]
   - Press (num, 4)
   - Depress (num, 4)

5. Exponent
   - Press (num, 1.2)
   - Depress (num, 1.2)

6. R^2 of regression
   - Press (num, 1.3)
   - Depress (num, 1.3)

7. Regression weighting (alpha, 1)

   C = Canadian (CSGB)
   L = LBL
   N = None
   O = Other
   U = Unknown

8. Leakage Area [cm^2]
   - Press (num, 5)
   - Depress (num, 5)

9. Air changes at 50 Pa [ACH]
   - Press (num, 2.1)
   - Depress (num, 2.1)

10. Canadian Leakage Area [cm^2] (num, 5)

11. Windspeed during test [m/s] (num, 2.1)

12. Temperature [^oC]
   - Inside (num, 3)
   - Outside (num, 3)

13. Who made measurement? (alpha, 1)

A = Research group
B = House doctor or contractor
C = City agency
D = State agency
E = Federal agency
F = Military
O = Other
U = Unreported

14. Measurement Rating (1-5) (alpha, 1)

1 = Best
2 = Better
3 = OK
4 = Not Good
5 = Terrible

15. Measurement Reference (alpha, 2)

16. Test Standard (alpha, 1)

A = ASTM
C = Canadian
O = Other
U = Unspecified

17. House Condition

- house doctored (y/n/u) (alpha, 1)
- weather stripped (y/n/u) (alpha, 1)
- caulked (y/n/u) (alpha, 1)
- modified windows (y/n/u) (alpha, 1)
- other retrofits (alpha, 1)

A = Attic bypasses sealed
B = Pocket door sealed
C = Furnace closet sealed
D = Ducts sealed
E = Window or wall air cond. covered
F = Fireplace damper added
H = Air-to-air heat exchanger
J = Vapor barrier
N = None

O = Other
Q = Wall and ceiling insulation, vapor barrier
S = Wall and floor insulation
T = Ceiling insulation
U = Unknown
V = Floor insulation
W = Wall insulation
X = Wall and ceiling insulation

II. HOUSE CHARACTERISTICS

1. House ID (alpha, 5)

2. Zip Code (alpha, 6)

3. City (alpha, 15)

4. State (alpha, 2)

5. House Type

   - # Stories (alpha, 1)
   - Floor type (alpha, 1)

     A = Unconditioned Basement
     B = Conditioned Basement
     C = Crawlspace
     D = Slab on Grade
     E = Crawlspace w/partial basement
     F = Slab w/partial basement
     O = Other
     U = Unreported

   - Roof type (alpha, 1)

     A = Flat Roof
     B = Unfinished Attic
     C = Finished Attic
     D = Cathedral Ceiling
     O = Other
     U = Unreported

   - Wall type (alpha, 1)

     A = Wood Frame
     B = Wood Frame w/Vapor Barrier
     C = Concrete Block
     D = Brick
     E = Block and Brick
     O = Other
     U = Unreported

- Building type (alpha, 1)

  A = Detached
  B = Duplex
  A = Townhouse
  O = Other
  U = Unreported

6. Equipment Type

   - Number of Fireplaces (def. = 9) (num, 1)
   - Number of Dampers (def. = 9) (num, 1)
   - Central Furnace (y/n/u) (alpha, 1)
   - Forced Air (y/n/u) (alpha, 1)
   - Conditioned ducts (y/n/u) (alpha, 1)

7. Year of Construction (alpha, 4)

8. Floor area
   - Conditioned [m^2] (num, 4)
   - Unconditioned [m^2] (num, 4)

9. Volume (conditioned) [m^3] (num, 5)

10. Height above grade [m] (num, 2.1)

11. Shielding Class (U for unknown) (alpha, 1)

12. Terrain Class (U for unknown) (alpha, 1)

13. Reference to Tracer gas measurements (alpha, 20)

14. Retrofit Activity (alpha, 50)

III. ZIPCODE

1. Zip Code (alpha, 6)
2. City (alpha, 15)
3. State (alpha, 2)
4. Census Region (alpha, 1)
5. Closest Weather Site (alpha, 15)
6. Specific Infiltration [$m^3/h\text{-}cm^2$]

   Total
   - Annual (num, 1.2)
   - Winter (num, 1.2)
   - Summer (num, 1.2)

   Stack
   - Annual (num, 1.2)
   - Winter (num, 1.2)
   - Summer (num, 1.2)

   Wind
   - Annual (num, 1.2)
   - Winter (num, 1.2)
   - Summer (num, 1.2)

7. Infiltration Degree Days [^{o}C-days]

   - Total (num, 5)
   - Heating (num, 5)
   - Cooling (num, 5)

APPENDIX II

```
STRUCTURE FOR FILE:   B:LEAKAGE .DBF
NUMBER OF RECORDS:    01100
DATE OF LAST UPDATE:  11/05/86
PRIMARY USE DATABASE
FLD         NAME        TYPE WIDTH    DEC
001         IDHOUSE      C     005
002         TESTNO       C     002
003         ZIPCODE      C     006
004         LEAKAGE      N     004
005         AVFLOWEXP    N     004     002
006         SPECLEAK     N     004     001
007         FLOW100      N     005
008         MEASRTG      C     001
009         DATEDAY      C     002
010         DATEMO       C     002
011         DATEYEAR     C     002
012         NOSEALVENT   N     001
013         NOCLODAMP    N     001
014         FIRSTTEST    C     001
015         POSTRETRO    C     001
** TOTAL **                  00042
.
```

```
STRUCTURE FOR FILE:   B:LEAKCHAR.DBF
NUMBER OF RECORDS:    01100
DATE OF LAST UPDATE: 11/03/86
PRIMARY USE DATABASE
FLD        NAME        TYPE WIDTH    DEC
001       IDHOUSE       C     005
002       TESTNO        C     002
003       ZIPCODE       C     006
004       COEFFPRESS    N     004
005       COEFFDEPRS    N     004
006       EXPPRESS      N     004     002
007       EXPDEPRESS    N     004     002
008       R2PRESS       N     005     003
009       R2DEPRESS     N     005     003
010       REGWT         C     001
011       LEAKPRS       N     005
012       LEAKDEPRS     N     005
013       AIRCHPRS      N     004     001
014       AIRCHDEPRS    N     004     001
015       CANLEAKAGE    N     005
016       WINDSPEED     N     004     001
017       TEMPIN        N     003
018       TMPOUT        N     003
019       MEASRDBY      C     001
020       MEASRTG       C     001
021       MEASREF       C     002
022       ASTMSTD       C     001
023       HOUSEDOC      C     001
024       WEATHSTR      C     001
025       CAULKED       C     001
026       WINDMOD       C     001
027       OTHERRETRO    C     001
** TOTAL **             00084
```

```
STRUCTURE FOR FILE:   B:HOUSCHAR.DBF
NUMBER OF RECORDS:    00752
DATE OF LAST UPDATE:  11/02/86
PRIMARY USE DATABASE
FLD         NAME         TYPE  WIDTH    DEC
001       IDHOUSE          C     005
002       ZIPCODE          C     006
003       CITY             C     015
004       STATE            C     002
005       HTYPESTORY       C     001
006       HTYPEFLOOR       C     001
007       HTYPEROOF        C     001
008       HTYPECONS        C     001
009       HOUSETYPE        C     001
010       FIRENO           N     001
011       DAMPERNO         N     001
012       CENFURN          C     001
013       FORCEAIR         C     001
014       ETYPEDUCTS       C     001
015       YRCONSTRCT       C     004
016       FLOORCOND        N     003
017       FLOORUNCND       N     003
018       VOLUME           N     004
019       HEIGHT           N     004     001
020       SCLASS           C     001
021       TERRAINCL        C     001
022       TGASMEAS         C     020
023       RETROACT         C     050
** TOTAL **                   00129
.
```

```
STRUCTURE FOR FILE:   B:ZIPCODE .DBF
NUMBER OF RECORDS:    00111
DATE OF LAST UPDATE: 10/28/86
PRIMARY USE DATABASE
FLD         NAME        TYPE WIDTH    DEC
001       ZIPCODE         C     006
002       CITY            C     015
003       STATE           C     002
004       CENSUSREGN      C     001
005       CLOSESTWTH      C     015
006       SPINANTOT       N     004     002
007       SPINWTTOT       N     004     002
008       SPINSMTOT       N     004     002
009       SPINANSTK       N     004     002
010       SPINWTSTK       N     004     002
011       SPINSMSTK       N     004     002
012       SPINANWND       N     004     002
013       SPINWTWND       N     004     002
014       SPINSMWND       N     004     002
015       INDGDYTOT       N     005
016       INDGDYHOT       N     005
017       INDGDYCLD       N     005
** TOTAL **                  00091
```

LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720