NATIONAL BUREAU OF STANDARDS REPORT

7152

INFILTRATION MEASUREMENTS IN TEN ELECTRICALLY HEATED HOUSES

by

Carl W. Coblentz
Paul R. Achenbach
and
Richard S. Gray

Report to

Rural Electrification Administration
U.S. Department of Agriculture
Washington 25, D. C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Mechanical Systems Section
Building Research Division

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1. INTRODUCTION

The National Bureau of Standards, in cooperation with the Rural Electrification Administration, made a field study of the air infiltration in ten electrically heated houses in the region of the Indiana Statewide Rural Electric Cooperative, Inc., to obtain information that could be used to better evaluate the heating load of similar houses. All houses were occupied at the time of the tests, which caused certain inconveniences to the occupants as well as to the investigating team, and also affected, somewhat, the control that could be maintained over the test conditions. Selection of about a dozen houses had been planned for the study of air infiltration, comprising various combinations of one- and two-story brick and frame construction built over basements, crawl spaces, or on concrete slabs-on-grade. Not all of these twelve different constructions were available for investigation in the Indiana Statewide Rural Electric Cooperative region, so ten residences which comprised a good variety of the desired features were selected.

2. DESCRIPTION OF HOUSES

The size, shape, and type of each of the ten houses investigated are illustrated by the floor plans of the living areas in Figures 1 through 10 at the end of the report. Pertinent data on the materials used in the walls, floors, and ceilings, the size of windows and doors, as well as the age of the houses, and type of heating system are shown in Tables 1 through 10 at the end of the report.

A summary of the more significant data on the materials and dimensions for all the houses is shown in Table 11. This table indicates that there were four brick, five frame, and one stone building, of which six were one-story high and four were two stories in height. Five buildings had a basement, four had a crawl space, and one building was built on a concrete slab-on-grade. There were four practically new houses, and the ages of the others ranged from 6 to 46 years, averaging 27 years. The heated floor area of the buildings ranged from 598 square feet to 2,490 square feet, with an average of 1,427 square feet.

The total lengths of cracks around doors and windows are shown in this table. These measurements were taken from the respective floor plans according to methods described in the ASHRAE "Guide" and were used in calculating the air infiltration values based on the crack length.

Table 11

Summary of Pertinent Data on Houses

House Occupant	Material in Walls	No. of Stories	Foundation	Age years	Heated Floor Area sq ft	Crack Length, ft Door	Windows Single	Windows Double
Hardy	Brick	1	Crawl sp.	20	1220	57		219
Hufford	Frame	1	Basement	30	1229	38	46	234
Craig	Brick	1	Crawl sp.	New	1510	38		162
Metzger	Frame	2	Basement	20	1230	38	90	189
Wrigley	Frame	2	Basement	40	1510	76	126	126
Spann	Stone	1	Basement	New	1658	80		226
Yeiter	Frame	1	Crawl sp.	New	1130	40		162
Dieckman	Frame	2	Crawl sp.	46	1696	56	8	252
Farnsley	Brick	2	Basement	New	2490	39		224
Lunsford	Brick Apt.	1	Slab	6	598	46		68

3. TEST METHOD AND PROCEDURE

Infiltration is defined as the air leakage of a building through cracks and interstices around doors and windows and through floors and walls that cannot be directly controlled by the occupants. Ventilation includes the controlled displacement of air in a building through openings, such as windows, doors, ventilators, and combustion heating devices using either natural or mechanical motivation. The magnitude of infiltration depends on the wind and temperature forces, and the structural design, workmanship, and condition of the building.

The air change rate of an enclosure is defined as the ratio of the hourly rate at which the air enters (or leaves) the enclosure to the volume of the enclosure.

The infiltration of air in each of the ten electrically heated houses was determined by the tracer gas method.[1] The apparatus used was the portable infiltration meter developed at the National Bureau of Standards.[2] Approximately 1/2 percent of helium in relation to the total volume of the house was introduced after the test apparatus had been brought to a temperature equilibrium in the house. The helium was mixed with the room air by using several desk fans. The outside doors and windows were closed, whereas closets and cupboards, and all inside doors were kept open, so the concentration of tracer gas would decay in these spaces at the same rate as in the living space. The ten sensing probes were placed near the centers of the rooms about 3 feet above floor level, and readings were taken at each probe station at 5-minute intervals for a period of 1 hour or more. During the test, the indoor and outdoor temperatures were measured as well as the wind velocity and direction in the vicinity of the house about 10 feet above ground. Two to four infiltration tests were made in each dwelling at prevailing conditions over a period of about 2 days.

1/ Marley, W. G., "The Measurement of the Rate of Air Change," Journal of the Institution of Heating and Ventilating Engineers, Vol. 2, 1935.

2/ Coblentz, C. W., and Achenbach, P. R., "Design and Performance of a Portable Infiltration Meter," Transactions, American Society of Heating and Air Conditioning Engineers, Vol. 63, 1957.

4. TEST RESULTS

A total of thirty infiltration tests were made. Two of these had to be omitted, however, because of significant changes in the infiltration rates during the test period, caused by opening of outside doors.

It was found that the most practical way of evaluating the readings of the infiltration meter was to plot them on semi-logarithmic graph paper. It can be shown that the air change rate in an enclosed space during a selected interval is directly proportional to the natural logarithm of the ratio of the concentration of the tracer gas at the beginning and end of the time interval, if the conditions remain constant. Thus, a constant infiltration rate would be represented by a straight line on semi-logarithmic graph paper.

The decay rate of the tracer gas at each station of observation during the twenty-eight tests made in the ten sample houses was plotted on semi-logarithmic graph paper to obtain an average air change rate, and to reveal the steadiness of the infiltration process. These data are shown in Figures 11 to 38 at the end of the report. Each figure shows the house identification, the location of each sensing element, and the computations used to determine the air change rate at each station and for the house as a whole.

In most instances, a straight line was a good representation of the decay curve. In the few cases where a straight line was not a good approximation of the decay curve, the data for these stations were not used in determining the average value for the house. The air change rate for the entire house was computed as the sum of the products of the infiltration rates in the individual rooms, and the corresponding percentage of the total house volume represented by each room. In cases where the infiltration data for a particular room was not usable, the volume of that room was not included in the total house volume. This procedure is tantamount to assuming that the infiltration rate of a room for which the data was not available or could not be used was equal to the average infiltration rate for the rest of the house.

Table 12 is a summary of the average infiltration rate for each test and shows the average wind velocity and prevailing direction, the inside-outside temperature difference, the observed air change rate, and an air change rate converted to a 10 mph wind velocity and an indoor-outdoor temperature difference of 40°F. The method of converting the observed values to a constant wind velocity and temperature difference will be discussed later in this report.

Table 12

Summary of Average Infiltration Rates in Sample Houses

House Occupant	Test Number	Approx. Avg. Wind Velocity mph	Prevailing Wind Direction	Indoor-Outdoor Temp. Diff. °F	Air Changes per Hour: Observed	Air Changes per Hour: Converted to 10 mph 40°F	Air Changes per Hour: Average Converted
Hardy	1	15	SW	45	0.84	0.67	
	2	15	W	45	0.77	0.62	
	3	15	WNW	48	0.77	0.60	0.63
	4	15	W	46	0.58	0.46	0.46*
Hufford	5	6	N	42	0.71	0.81	
	6	6	N	43	0.56	0.63	
	7	11	S	43	0.91	0.85	0.76
Craig	8	11	SW	27	0.51	0.58	
	9	15	SW	23	0.42	0.43	
	10	10	SSW	23	0.35	0.44	0.48
Metzger	11	13	SSW	24.5	1.13	1.22	
	12	12	SSW	20	0.85	1.03	
	13	12	SW	29	0.67	0.71	0.99
Wrigley	14	11	W	41	0.94	0.87	
	15	10	W	41.5	0.80	0.78	
	16	6	NW	44	0.79	0.85	
	17	11	N	45.5	0.96	0.86	0.84
Spann	18	6	WSW	54.5	0.55	0.53	
	19	12	WSW	49.5	0.39	0.33	
	20	8	WSW	46	0.23	0.23	0.36
Yeiter	21	6	NW	48	0.59	0.62	
	22	6	SW	50	0.42	0.43	0.53
Dieckman	23	6	NE - SW	38	0.59	0.71	
	24	6	SW	42.5	0.63	0.71	
	25	8	NW	53	0.67	0.62	0.68
Farnsley	27	11	W	46	0.50	0.51	0.51
Lunsford	28	6	NE	42.5	0.58	0.65	
	30	8	W	63.5	0.81	0.66	0.66

* Closed exhaust vents in kitchen and bathroom.

The average wind velocities that prevailed during the air infiltration tests ranged from 6 to 15 mph, and the inside-outside temperature differences were between 21° and 53°F. This variation in conditions made it difficult to correlate the air change rate with the actual air tightness of the houses. Not enough tests were made with any one house to evaluate directly the effects of wind velocity and temperature difference on the infiltration rate so a direct comparison could be made between houses at a selected climatic condition.

An empirical formula was used, therefore, to convert the observed infiltration rates to a uniform condition of wind velocity and temperature difference that was near to the average of the observed test conditions. Published information[3/,4/] on infiltration measurements in two test houses at the University of Illinois indicated that the air change rate in each was directly proportional to the indoor-outdoor temperature difference and to the wind velocity, and that the infiltration rate with no wind and no indoor-outdoor temperature difference ranged from 0.12 to 0.18 air change. The University of Illinois data further showed that an increase in wind velocity of 1 mph was equivalent to an increase of two or four degrees F in temperature difference in its effect on the infiltration rate. Thus, an equation of the form of equation (1) can be used to approximate the effect of wind and temperature difference on the air change rate.

$$A.C. = K\,(0.1 + 0.03W + 0.01T) \qquad (1)$$

where A.C. = hourly air change rate
W = wind velocity, mph
T = inside-outside temperature difference, °F
K = a constant depending on the air tightness and height of the building.

3/ Bahnfleth, D. R., et al, "Measurement of Infiltration into Residences," Part I, Transactions, American Society of Heating and Air Conditioning Engineers, Vol. 63, 1957.

4/ Same as above, Part II.

A wind velocity of 10 mph and a temperature difference of 40°F were used as a basis for comparing the infiltration rate of the several houses since it approximated the mean of the observed conditions. Thus, the computed air change rate (A.C.') at this selected condition could be determined by equation (2).

$$A.C.' = \frac{0.1 + (0.03 \times 10) + (0.01 \times 40)}{0.1 + 0.03W + 0.01T} \times A.C. \qquad (2)$$

where, A.C., W, and T were the observed values in any given test.

Table 12 shows the air change rate for each test converted by equation (2) to a wind velocity of 10 mph and a temperature difference of 40°F. The table also shows the average converted value for all tests in each house. These converted values should be considered as approximate values because the absolute and relative values of the constants in equation (1) probably vary from house to house.

Table 13 summarizes the converted air change rates in relation to the type of building construction and foundation, and building height. It shows that the infiltration rate ranged from 0.36 to 0.99 air change under the same conditions. Since only one house in each category was tested, conclusions should not be drawn about categorical differences in air tightness of the different types of houses. The measured air infiltration rates of the two test houses[3/, 4/] at the University of Illinois for these same wind and temperature conditions was 0.40 for a two-story brick veneer house over a basement and 0.58 for a single-story frame house over a basement.

Table 13 shows two values for the converted air change rate of the Hardy house. The first value, 0.63, was the average of three tests made with the exhaust vents in the kitchen and bathroom open, whereas the second value, 0.46, was obtained with these vents closed. Since the volume of the Hardy house was 9,760 cubic feet, it appears that these two vents produced a combined ventilation of about 1,660 cubic feet per hour.

Table 13

Air Change Rates of Residences, Converted to 10 mph Wind Velocity and 40°F Temperature Gradient

Type of Foundation	Wall Material	Number of Stories	
		One	Two
Basement	Stone	0.36	
	Brick	0.48	0.51
	Frame	0.76	0.99
Crawl space	Brick	(0.63)(0.46)*	
	Frame	0.53	0.68
Slab-on-grade	Brick	0.66	

* Closed exhaust vents in kitchen and bathroom.

The air infiltration of the buildings was also calculated using the crack method as outlined in the ASHRAE "Guide," 38th edition, 1960. For the purpose of this computation, it was assumed that all windows were weatherstripped, and a wind velocity of 15 mph was selected. According to the "Guide," the infiltration rate of 24 cubic feet per hour per foot of crack length for single double-hung wood sash windows was halved for double windows, and the air flow rate for doors was selected at 55 cubic feet per hour per foot perimeter. The value computed by this method for each of the houses is shown in the third column of Table 14. The last two columns in the table show the average values of observed infiltration rates and of these rates converted to a wind velocity of 10 mph and an inside-outside temperature difference of 40°F.

It will be noted that there is a better than ± 10 percent agreement between the infiltration rates calculated by the crack method and the converted values on seven of the ten houses studied even though the infiltration computation by the crack method was based on a 15 mph wind and does not take temperature difference into account as a variable. The Spann residence shows a computed crack length infiltration rate 50 percent higher than that converted from the test results, and the infiltration of the Dieckman residence as calculated by the crack method was approximately 30 percent lower than the corresponding converted value.

Table 14

Comparison of Air Change Rates Computed
by the Crack Method and Average Observed Values

House Occupant	Description of Building	Computed by Crack Method for 15 mph Wind	Observed, Actual	Converted from Observed Data to 10 mph 40°F
Hardy	1-story Brick, crawl space	0.59	0.74	0.59
Hufford	1-story Frame, basement	0.70	0.73	0.76
Craig	1-story Brick, basement	0.53	0.43	0.48
Metzger	2-story Frame, basement	0.94	0.88	0.99
Wrigley	2-story Frame, basement	0.75	0.87	0.84
Spann	1-story Stone, basement	0.54	0.39	0.36
Yeiter	1-story Frame, crawl space	0.49	0.51	0.53
Dieckman	2-story Frame, crawl space	0.47	0.68	0.68
Farnsley	2-story Brick, basement	0.55	0.50	0.51
Lunsford	1-story Brick, on slab	0.70	0.70	0.66

Table 1

E. Hardy Residence, Rt. 3, Greenfield

1-Story Brick House over Crawl Space
20 years old, Heated Floor Area 1220 ft^2

Walls:
- 4" Brick
- 3 5/8" Studs
- 1/2" Plaster and Rock Lath
- .002" Vapor Barrier

Ceiling (open):
- 1/2" Plaster and Rock Lath
- 2" x 6" Joists

Floor:
- 1" x 6" and 8" Subflooring
- 3/8" Plywood, with Vinyl Tile over
- .002" Vapor Barrier

Insulation:
- Walls - Double-Blown Cellulose Fiber
- Ceiling - Loose Cellulose Fiber
- Floor - 3 1/2" Cellulose Fiber Batts

Roof:
- Pitch - 5'-2"/16'-6"
- Height - 8'-0"
- Overhang - 18"
- Louvers - Twelve, 4" x 12"

Basement:
- None (crawl space)

Windows:
- Double-hung, wood sash, with aluminum storm, caulked, sealed double glass in living room

Doors:
- Side (to garage) - Solid wood
- Rear - Wood with 1/2 glass, with storm
- Front - Wood, with storm

Heating:
- Electric baseboard

Table 2

T. E. Hufford Residence, Rt. 1, Charlottsville

1-Story Frame House over Basement
30 years old, Heated Floor Area 1229 ft^2

Walls:
1/2" Wood Lap Siding
Building Paper
1" Sheathing
2" x 4" Studs
1" Plaster and Wood Lath

Ceiling:
1" Plaster and Wood Lath
2" x 6" Joists
1" Wood Flooring (except over living room)

Floor:
1" Pine Finish (no subflooring)
2" x 6" Joists

Insulation:
Walls - 4" Rock Wool
Ceiling - 4" Rock Wool, 2" Cellulose Fiber
Floor - None

Roof:
Pitch - 4/12
Louvers - One, 4" x 12", two, 4" x 8"

Basement:
Full, except under porch, no insulation or vapor barrier; walls are cement block to ground level with brick above to house frame; unheated

Windows:
Wood sash, storm windows in bedroom 2 and center sash of bedroom 1 only, in attic there are 3 windows (front, rear, north)

Doors:
Wood with 1/2 glass and storm to front and carport

Heating:
Electric baseboard

Table 3

J. S. Craig Residence, RR. 1, Wabash

1-Story Brick with Basement and Crawl Space
New House, Heated Floor Area 1510 ft^2

Walls:
- 4" Brick Veneer
- 1" Sheathing
- 2" x 4" Studs
- 1/2" Plaster and Rock Lath
- Vapor Barrier

Ceiling:
- 1/2" Plaster and Rock Lath
- 2" x 6" Joists
- Vapor Barrier

Floor:
- 5/8" Finish Flooring
- 3/4" Subflooring
- 2" x 10" Joists
- 1/2" Plaster and Rock Lath

Insulation:
- Walls - 4" Cellulose Fiber
- Ceiling - 6" Cellulose Fiber
- Floor - 2" Batts (Alfol)

Roof:
- Pitch - 4/12
- Overhang - 24"
- Eave Vents - Twelve, 8" x 12"
- Exhaust Fans

Basement:
- Under kitchen, living room, dining room; plastered ceiling, cement block walls, concrete floor; rest is crawl space open to basement

Windows:
- Casement with storm in bedroom 1, dining room, kitchen, casement with storm in baths, bedroom 2, sealed double glass in living room, four 12" x 15" single pane in basement

Doors:
- Combination aluminum in front; all others solid wood

Heating:
- Electric ceiling cable

Glass doors in fireplace

Table 4

D. A. Metzger Residence, RR. 3, N. Manchester, Ind.

2-Story Frame with Cinder Block Basement
20 years old, Heated Floor Area 1230 ft^2

Walls:
- 1/4" Asbestos Shingles
- Building Paper
- 1" Wood Sheathing
- 2" x 4" Studs
- 1/2" Plaster and Lath

Ceiling (open):
- 1st Floor (8')
  - 1/2" Plaster and Lath
  - 2" x 6" Joists
  - 1" Subflooring
- 2nd Floor (7 1/2')
  - 1/2" Plaster and Lath
  - 2" x 6" Joists

Floor:
- 1/2" Finish (Pine)
- 1/2" Subflooring (Pine)
- 2" x 8" Joists

Insulation:
- Walls - 3 5/8" Blown Cellulose Fiber
- Ceiling - 6" Blown Cellulose Fiber
- Floor - 2" Batts (Alfol), "U" is .04

Roof:
- Pitch - 4/12
- Overhang - 24"
- Louvers - Four, 4" x 12"

Basement:
Under kitchen and bedroom 1, other area is crawl space, walls are concrete block with two 18" x 24" casement windows; crawl space opens into basement; unheated

Windows:
Wood sash, no storm in living room towards porch; wood sash with storm on all other rooms

Doors:
Wood with 1/2 glass

Heating:
Electric baseboard

Exhaust fans in bathroom and kitchen

Table 5

R. Wrigley Residence, Rt. 3, Warsaw, Ind.

2-Story Frame House over Basement
40 years old, Heated Floor Area, 1510 ft^2

Walls:
- 1/4" Asbestos Siding
- 5/8" Wood Sheathing
- 2" x 4" Studs
- 1" Plaster and Lath

Ceiling (open):
- 1st Floor (9')
  - 1" Plaster and Lath
  - 2" x 6" Joists
  - 1" Flooring
- 2nd Floor (8')
  - 1" Plaster and Lath
  - 2" x 6" Joists

Floor:
- 1" Flooring
- 1/2" Subflooring
- 2" x 8" Joists

Insulation:
- Walls - 3 5/8" Blown Cellulose Fiber
- Ceiling - 6" Blown Cellulose Fiber, and 4" Rock Wool, 10 years old
- Floor - 3 5/8" Cellulose Fiber Batts

Roof (Asbestos Shingles):
- Pitch - 1/2
- Overhang - 18"
- Louvers - Six, 10" x 10"
- Exhaust Fans - 1 in kitchen

Basement:
Full, except for crawl space under porches and office; poured cement walls, five 12" x 18" casement windows; unheated

Windows:
Wood, single pane, with storm windows on first floor only

Doors:
Wood, with storm door on west entrance

Heating:
Electric baseboard

Table 6

M. Spann Residence, RR. 1, Pierceton

1-Story Stone Veneer over Basement
New House, Heated Floor Area 1658 ft^2

Walls:
- 4" Stone Veneer
- 1" Sheathing
- 2" x 4" Studs
- 1/2" Plaster and Rock Lath

Ceiling:
- 1/2" Plaster and Rock Lath
- 2" x 8" Joists

Floor:
- 1/2" Pine Finish
- 1/2" Subflooring (Pine)
- 2" x 10" Joists

Insulation:
- Walls - 3 1/2" Foil Backed Fiber Glass
- Ceiling - 6" Fiber Glass, 4" Cellulose Fiber
- Floor - 3 1/2" Foil Backed Fiber Glass

Roof (Wood Shingles):
- Pitch - 4 1/2 /12
- Overhang - 2'-6"
- Louvers - Two, 12" x 24"

Basement:
- 12" Cement Block Walls
- 8" Poured Cement Floor
- Height - 7 1/2'

Windows:
- Sealed double glass throughout

Doors:
- Solid wood with storm on east side, sliding double glass door on west side, 2 wood with 1/2 glass and storm on south side

Heating:
- Electric cable (ceiling panel)

Exhaust fans in kitchen and bathroom

Table 7

B. Yeiter Residence, RR. 4, Warsaw

1-Story Frame House over Crawl Space
New House, Heated Floor Area 1130 ft^2

Walls:
- 1/2" Redwood Cap Siding
- Aluminum Foil
- 1" Ship Lap Siding (Pine)
- 2" x 4" Studs
- Vapor Barrier
- 1/2" Plaster and Rock Lath

Ceiling:
- 1/2" Plaster and Rock Lath
- 2" x 6" Joists
- Height - 7'-6"

Floor:
- Tile
- 1/4" Building Board Underlay
- 1" Ship Lap (Pine)
- 2" x 10" Joists
- Vapor Barrier

Insulation:
- Walls - 3 5/8" Cellulose Fiber
- Ceiling - 6" Cellulose Fiber
- Floor - 3" Rock Wool

Roof (Asphalt Shingles):
- Pitch - 4/12
- Overhang - 24"
- Louvers - Two, 270 sq in.

Basement:
- None; crawl space, 2' high open crawl space with vapor barrier on ground

Windows:
- Sealed double glass throughout

Doors:
- Solid wood with storm

Heating:
- Electric baseboard

Table 8

W. Dieckman Residence, RR., Greenburg, Ind.

2-Story Frame House over Crawl Space
46 years old, Heated Floor Area 1696 ft^2

Walls:
- 1/2" Wood Lap Siding
- 3/4" Wood Sheathing
- 2" x 4" Studs
- 1" Plaster and Wood Lath

Ceiling:
- 1st Floor (9'4")
  - 1" Plaster and Wood Lath
  - 2" x 6" Joists
  - 1" Flooring
- 2nd Floor (7'-6")
  - 1" Plaster and Wood Lath
  - 2" x 6" Joists

Floor:
- 1/2" Oak Finish
- 1/2" Subflooring
- 2" x 10" Joists

Insulation:
- Walls - 3 5/8" Blown Cellulose Fiber
- Ceiling - 6" Blown Cellulose Fiber
- Floor - None, and none between 1st and 2nd floors

Roof:
- Pitch - 1/2
- Louvers - Two, 6" x 6", and three, 12" x 12"

Basement:
- None (crawl space), 18" clearance; two, 12" x 24" openings

Windows:
- Wood sash with storm in heated spaces, except there is no storm on first floor closet window

Doors:
- Wood with 1/2 glass, with aluminum storm on all except door to unheated porch which is an aluminum storm door

Heating:
- Baseboard

No vapor barrier; exhaust fan in kitchen

Table 9

C. Farnsley Residence, Georgetown, Ind.

2-Story Brick House over Basement
New House, Heated Floor Area 2490 ft^2

Walls:
4" Brick Veneer
Building Paper
3/4" Storm Sheathing
2" x 4" Studs
Vapor Barrier
3/4" Plaster and Rock Lath

Ceiling:
1st Floor (8')
1/2" Plaster and Rock Lath
2" x 8" Joists
3/4" Subflooring
1/4" Masonite

2nd Floor (6 1/2')
1/2" Plaster and Rock Lath
2" x 6" Joists

Floor:
1/4" Masonite
3/4" Subflooring (Fir)
2" x 4" Joists

Insulation:
Walls - 3 5/8" Blown Cellulose Fiber
Ceiling - 1st Floor (8'); 7 5/8" Blown Cellulose Fiber
2nd Floor (6 1/2'); 6" Blown Cellulose Fiber
and 3 5/8" between rafters
Floor - None

Roof:
Pitch - 8/12
Overhang - None
Louvers - Four, 72-sq-in. triangles

Windows:
Aluminum with storm

Doors:
Front - Solid wood with storm
Side - Wood with 1/2 glass, no storm

Vapor Barrier:
Placed in floor, wall and ceiling

Exhaust fan in kitchen

Table 10

R. E. Lunsford Residence, W. Campbell St., Indianapolis, Ind.

1-Story Brick Apartment over Concrete Slab
6 years old, Heated Floor Area 598 ft^2

Walls:
- 4" Brick Veneer
- 1" Sheathing
- 2" x 4" Studs
- Vapor Barrier
- 1/2" Plaster and Rock Lath

Ceiling:
- 1/2" Plaster and Rock Lath
- 2" x 6" Joists
- Height - 8'

Floor:
- 5" Thick Concrete Slab

Insulation:
- Floor - 1" Fiber Glass Board Perimeter Insulation (2' down and 2' in)
- Ceiling - 6" Blown Glass Fiber
- Walls - 3 5/8" Fiber Glass Batts

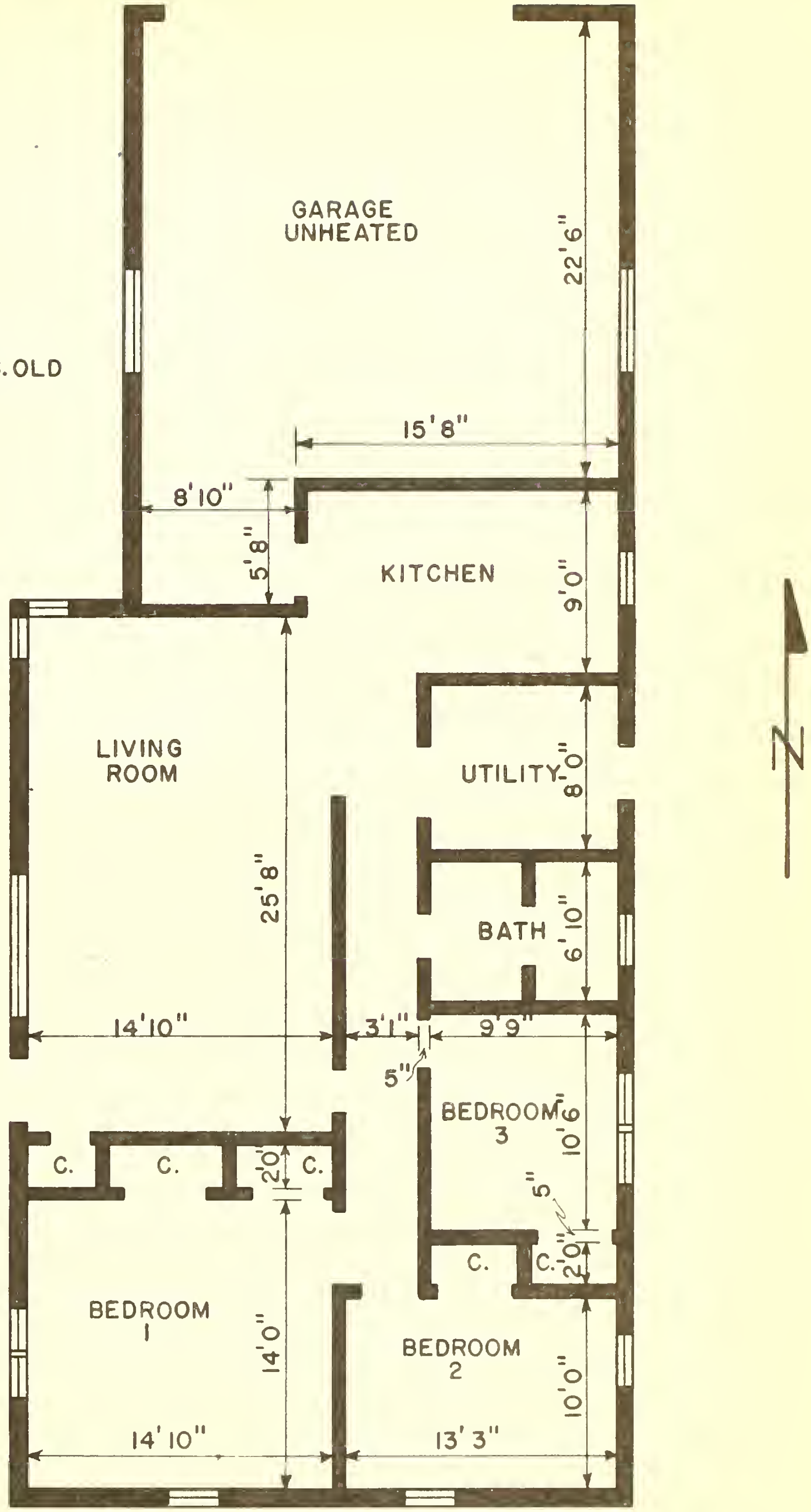
Roof (Asphalt Shingles):
- Pitch - 2/12
- Overhang - 12"

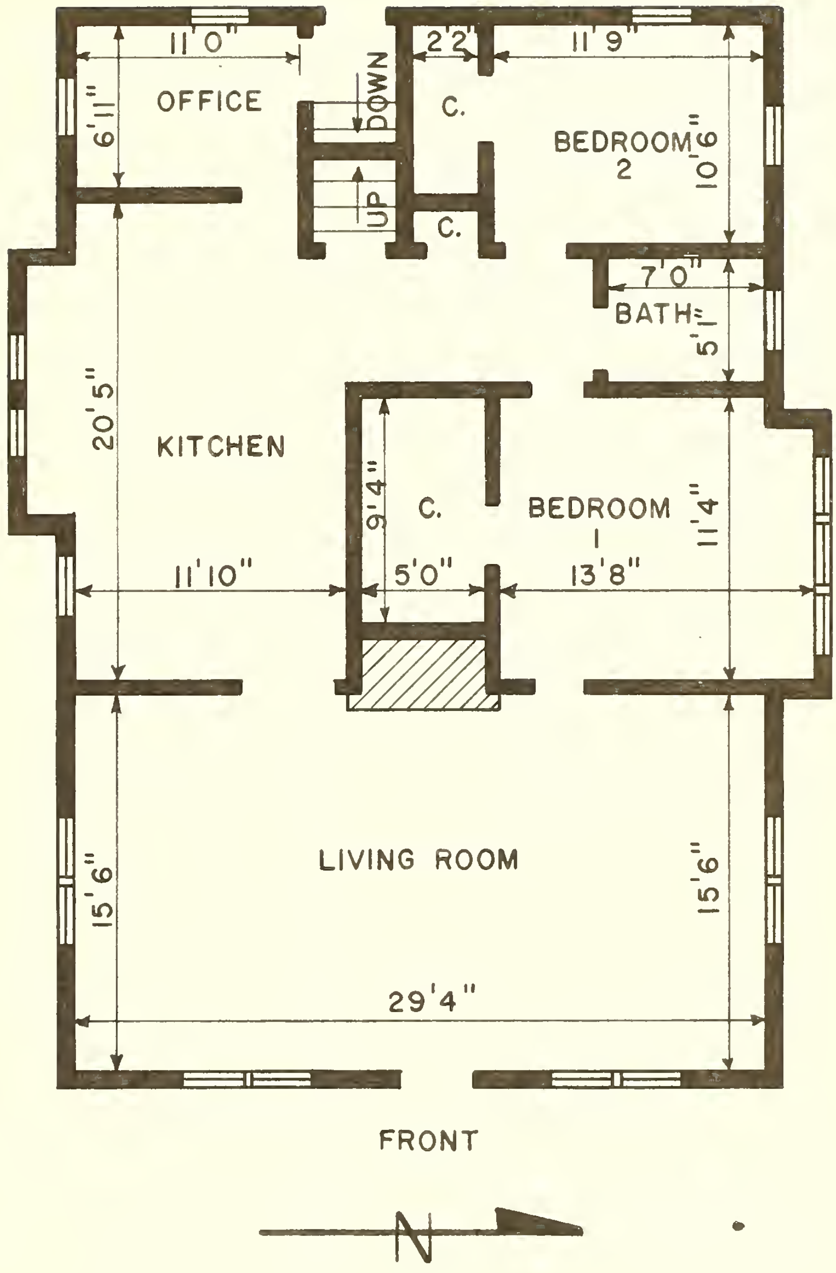
Windows:
- Sealed double glass

Doors:
- North - Wood with 1/2 glass and storm
- South - Sliding, double glass

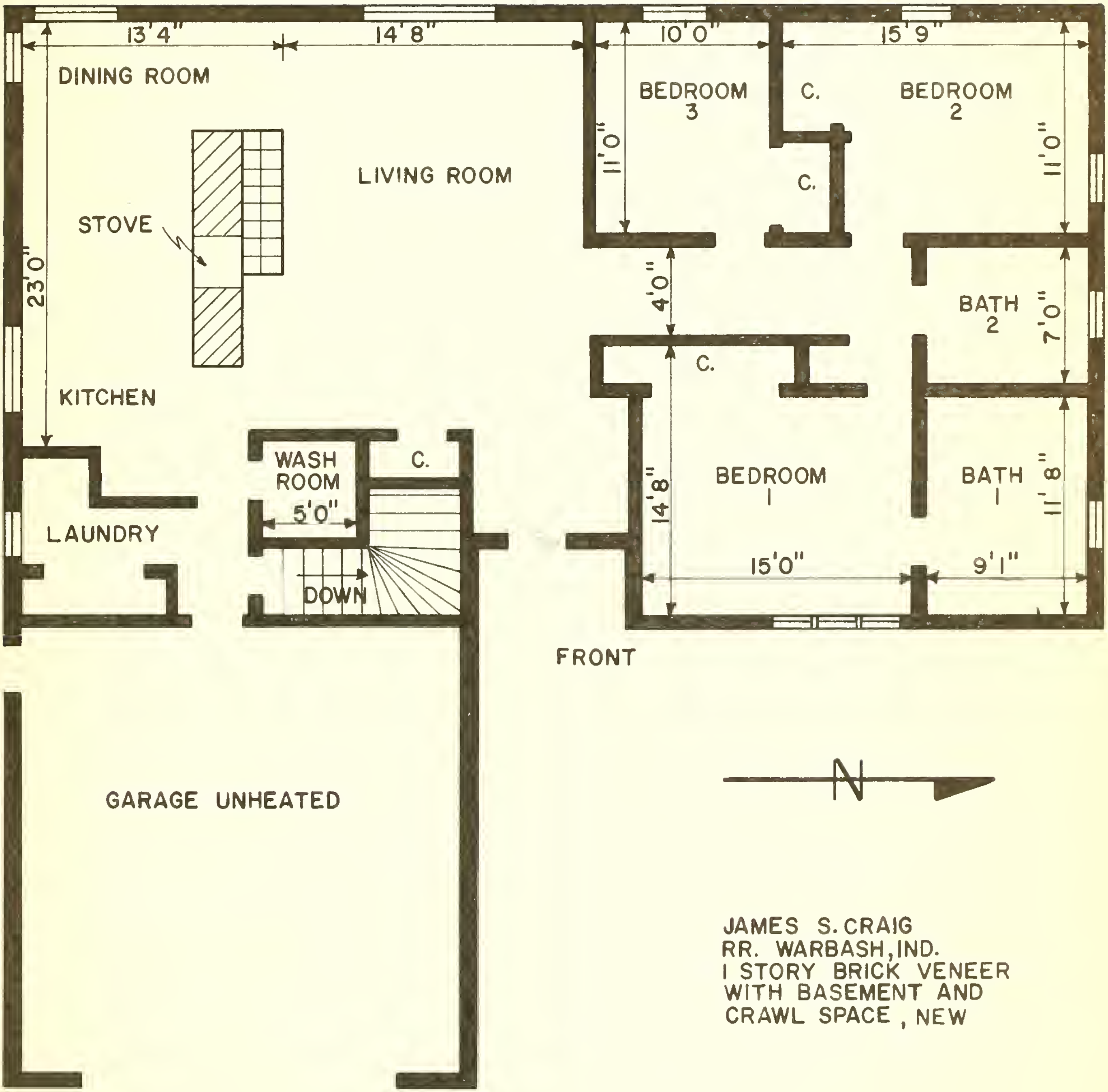
EUGENE HARDY
RT 3, GREENFIELD, IND.
I STORY BRICK OVER
CRAWL SPACE, 20 YRS. OLD

FRONT

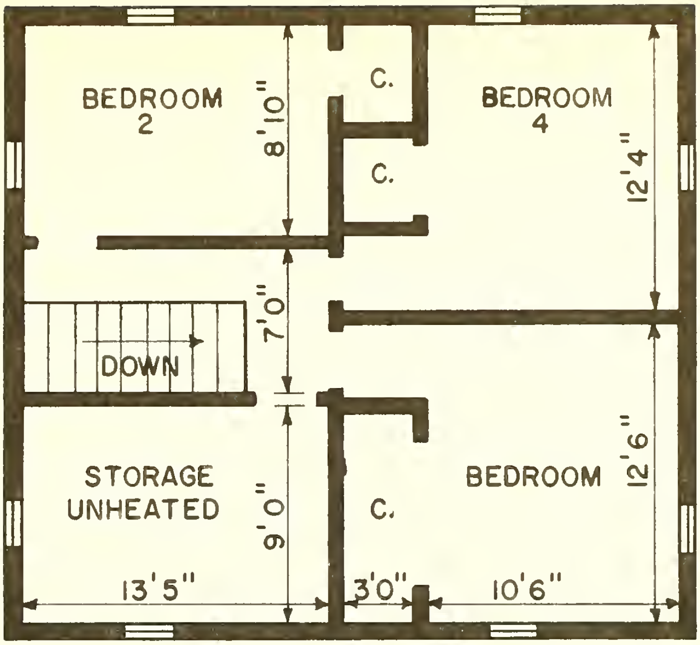




T.E. HUFFORD
RR 1, CHARLOTTESVILLE, IND.
1 STORY FRAME OVER BASEMENT,
30 YEARS OLD



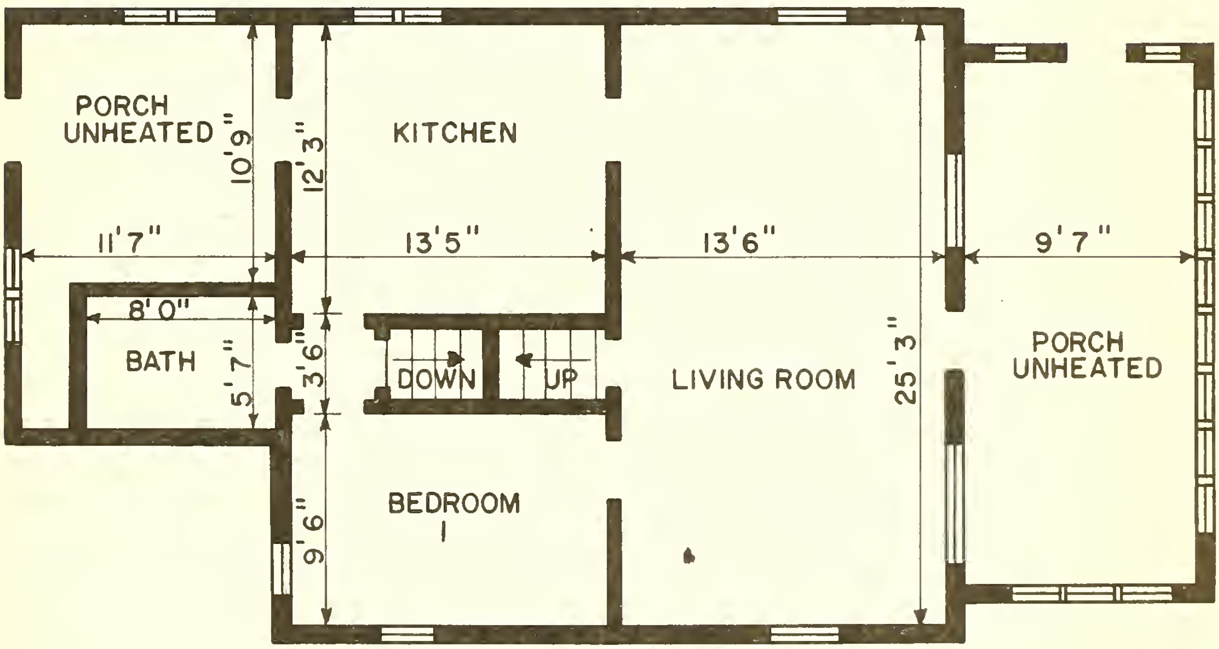
JAMES S. CRAIG
RR. WARBASH, IND.
I STORY BRICK VENEER
WITH BASEMENT AND
CRAWL SPACE, NEW



2 ND FLOOR

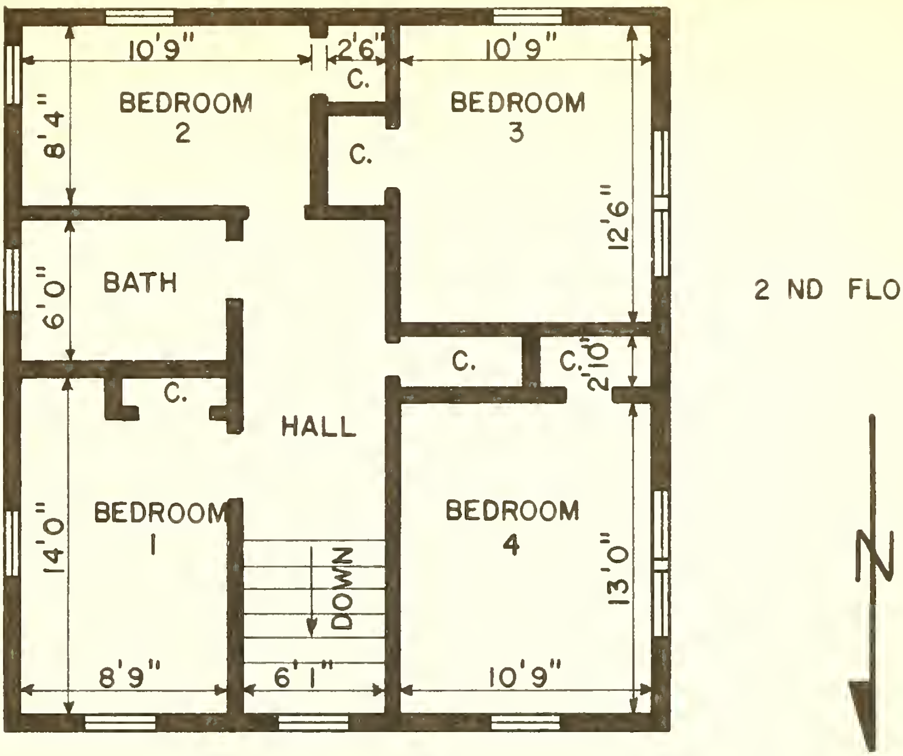
DONALD A. METZGER
RR # 3, N. MANCHESTER, IND.
2 STORY FRAME OVER
BASEMENT, 20 YEARS OLD

FRONT



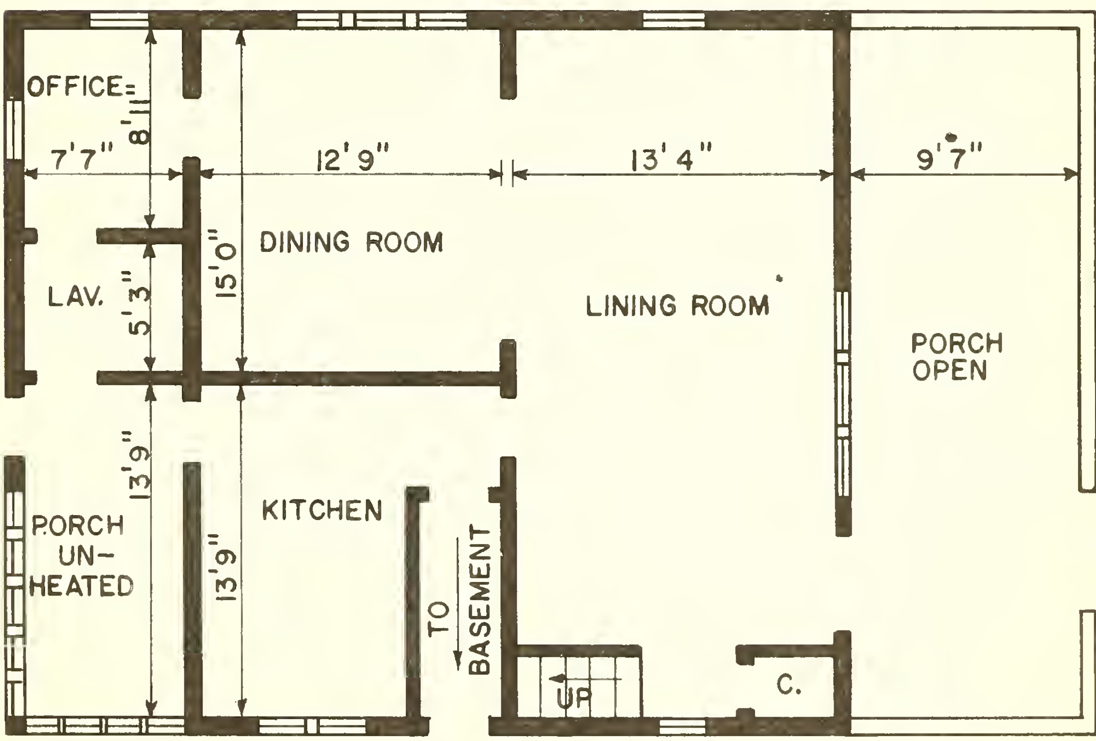
I ST FLOOR

N



2 ND FLOOR

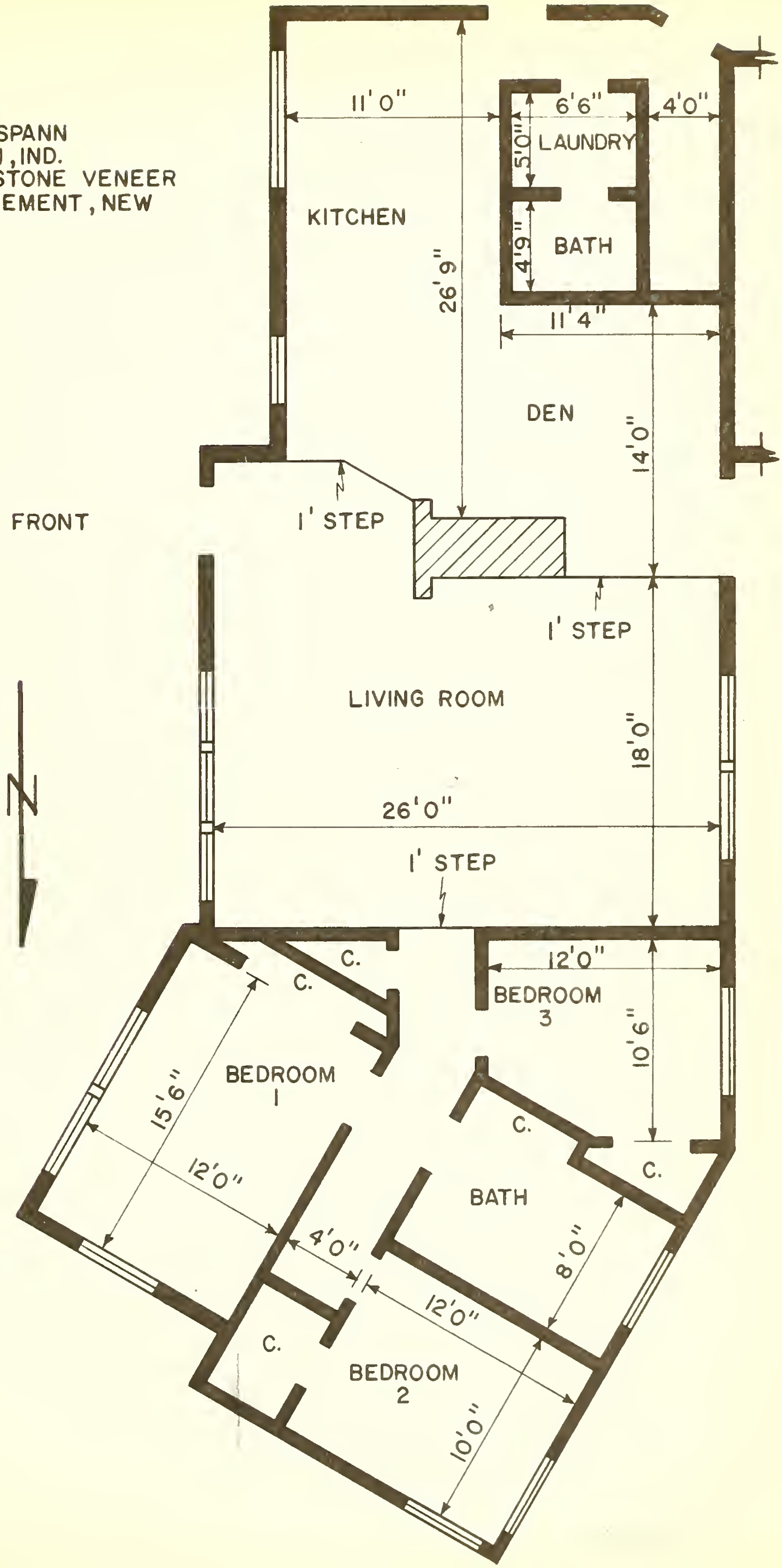
RALPH WRIGLEY
RT # 3, WARSAW IND.
2 STORY FRAME OVER
BASEMENT, 40 YEARS OLD



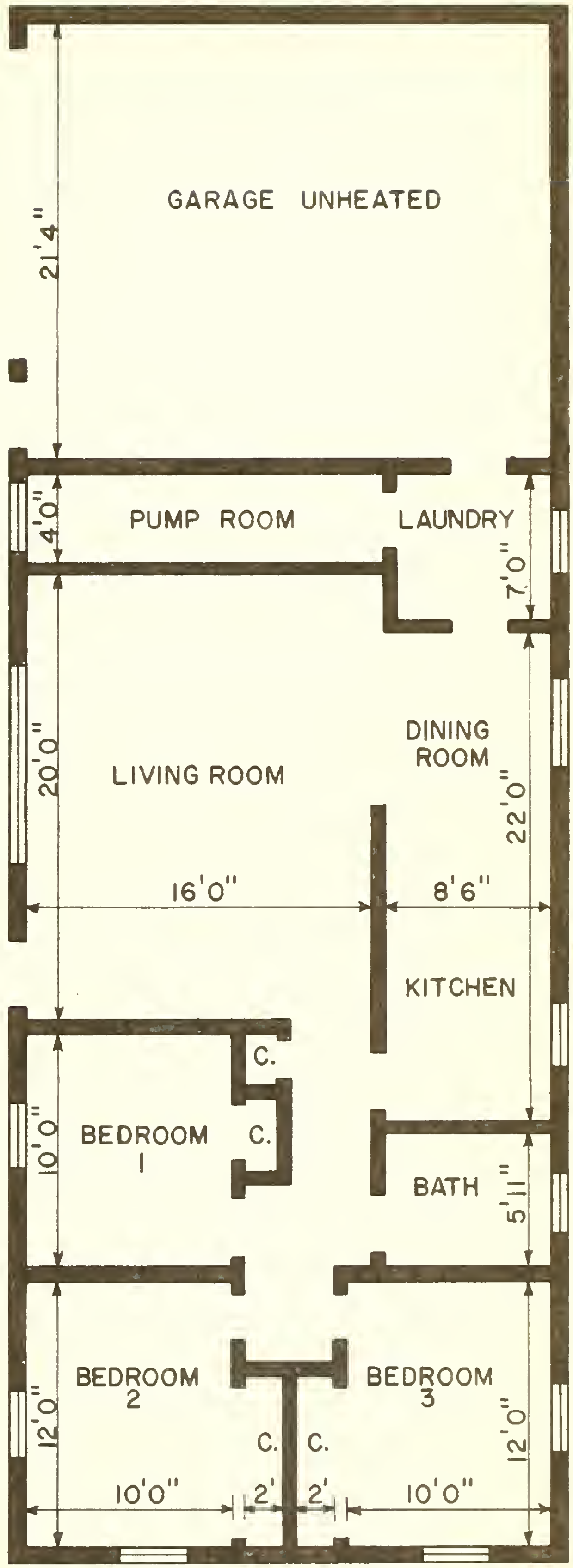
FRONT

1 ST FLOOR

MAYNARD SPANN
PIERCETON, IND.
1 STORY STONE VENEER
OVER BASEMENT, NEW

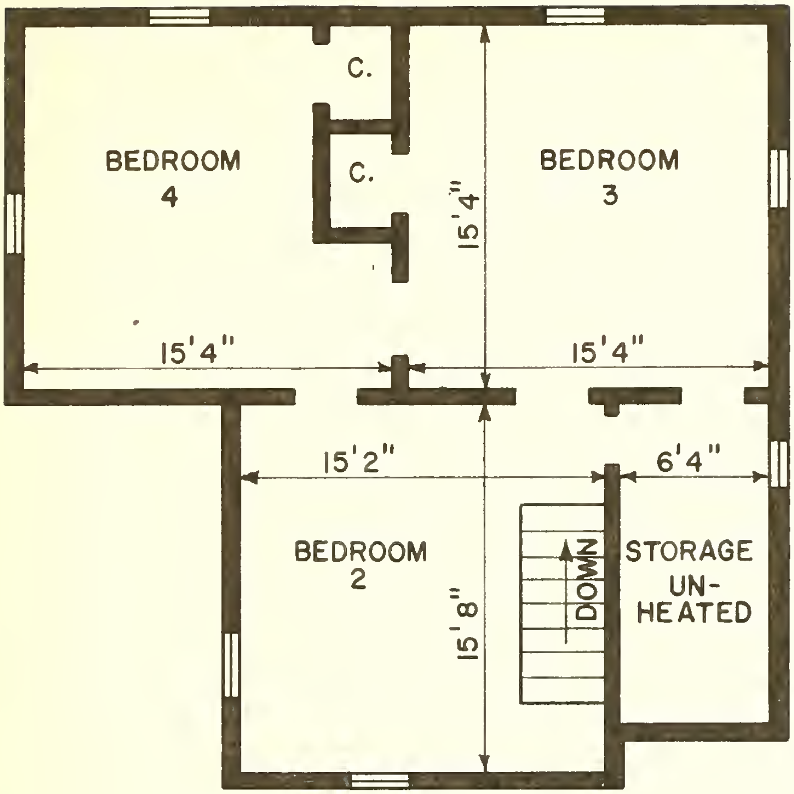


FRONT

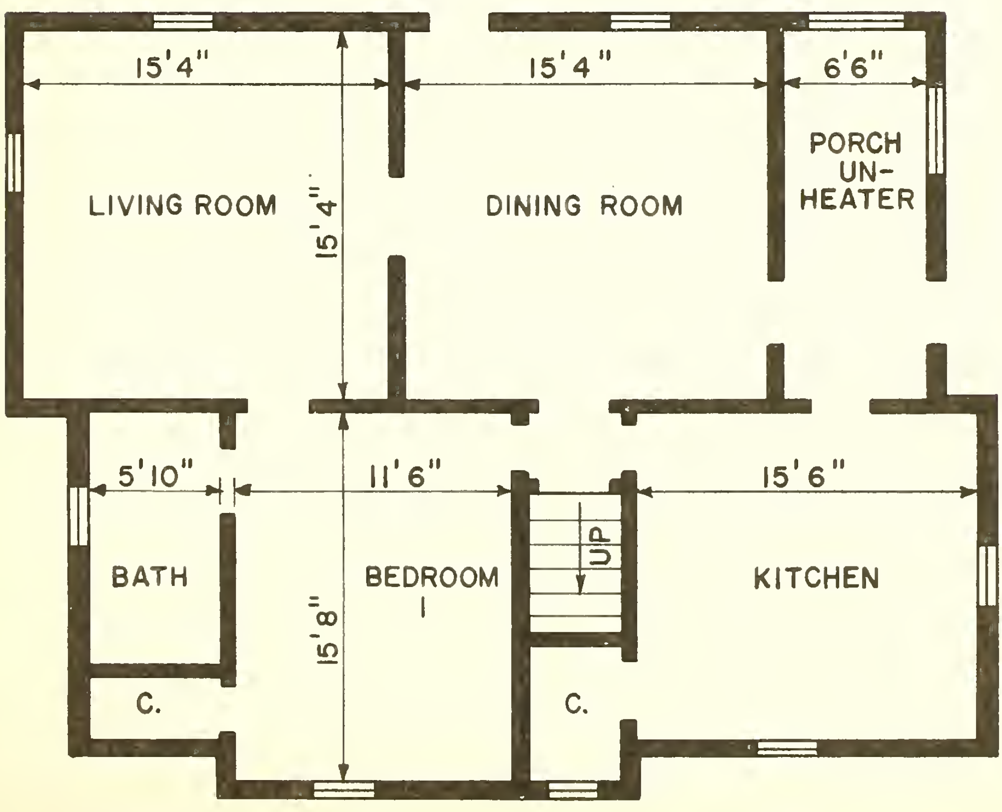


BERYL YEITER
RR 4, WARSAW, IND.
1 STORY FRAME OVER
CRAWL SPACE, NEW

WILBUR DIECKMAN
RR, GREENBURG, IND.
2 STORY FRAME OVER
CRAWL SPACE, 46 YRS. OLD



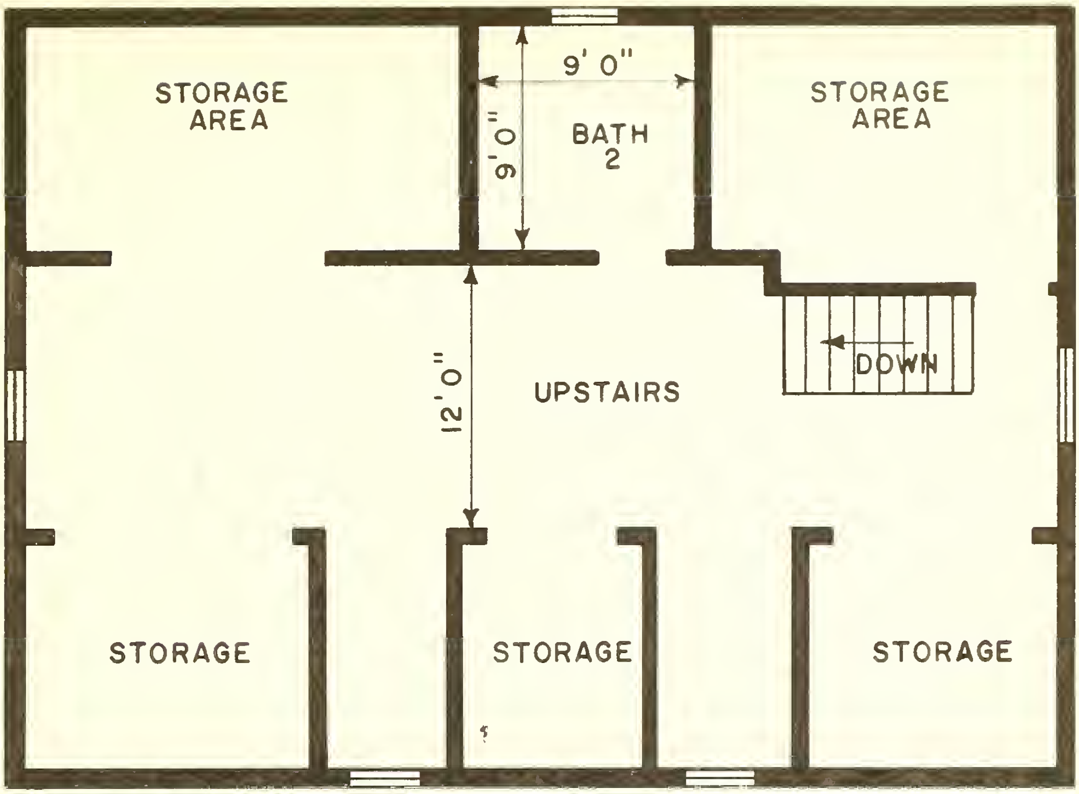
2 ND FLOOR



1 ST FLOOR

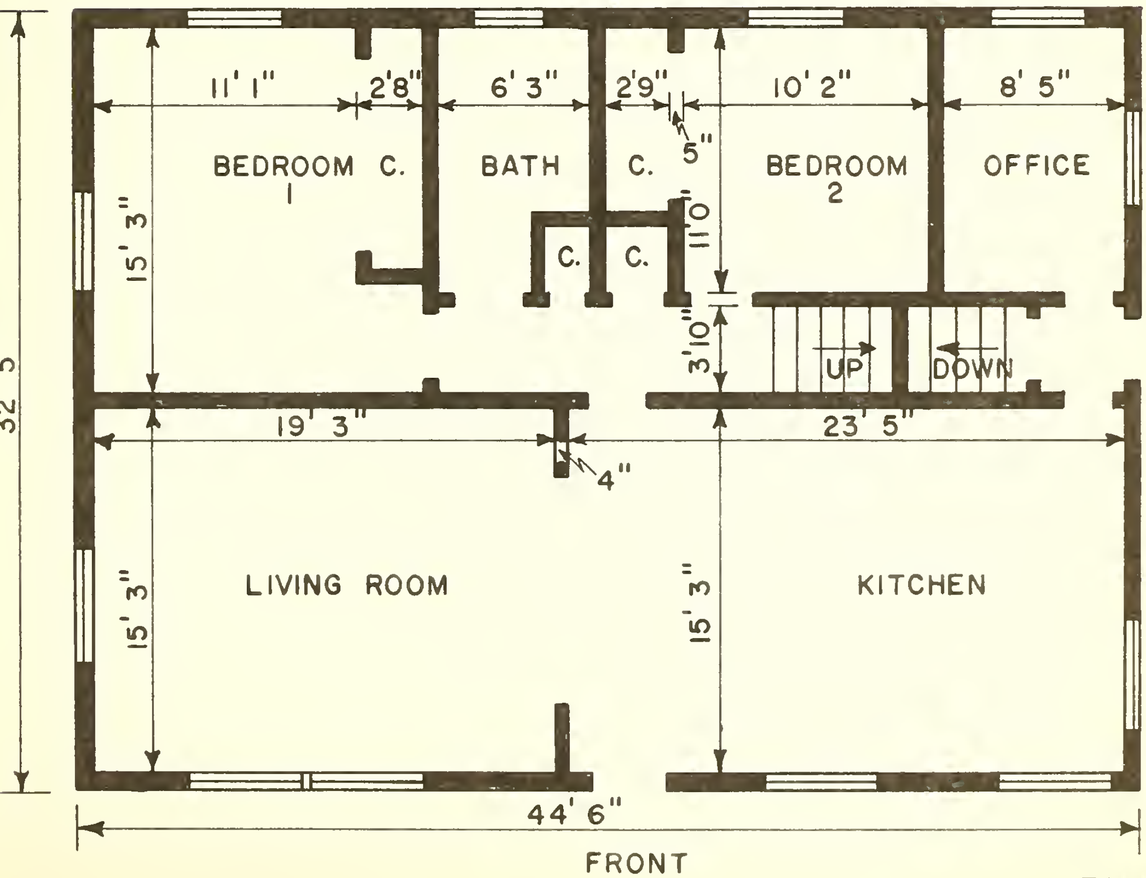
FRONT

Figure [illegible]

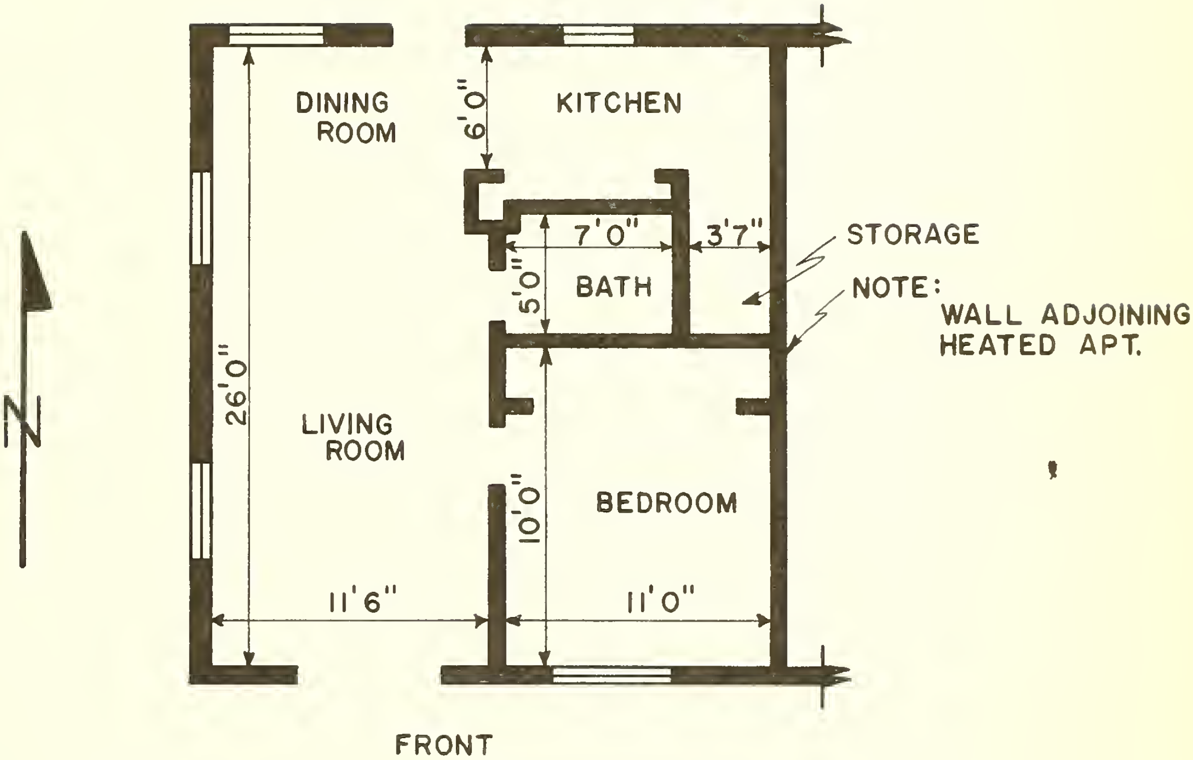


SECOND FLOOR

CHARLES FARNSLEY
RR2, GEORGETOWN, IND.
2 STORY BRICK OVER BASEMENT, NEW



FIRST FLOOR



R.E. LUNSFORD
W. CAMPBELL ST.
INDIANAPOLIS, IND.
1 STORY BRICK VENEER
APT. ON SLAB, 6 YRS. OLD

Figure 10

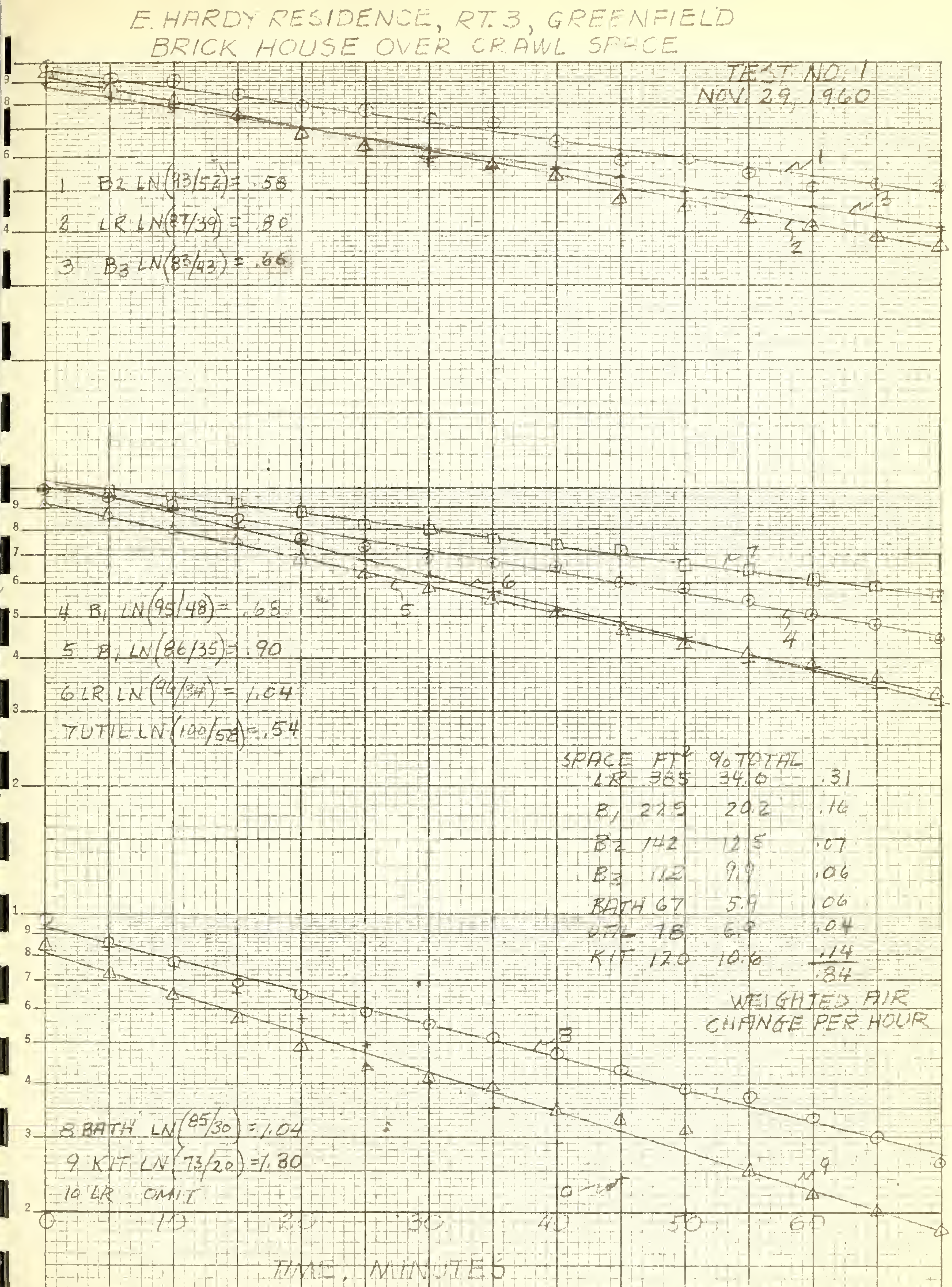
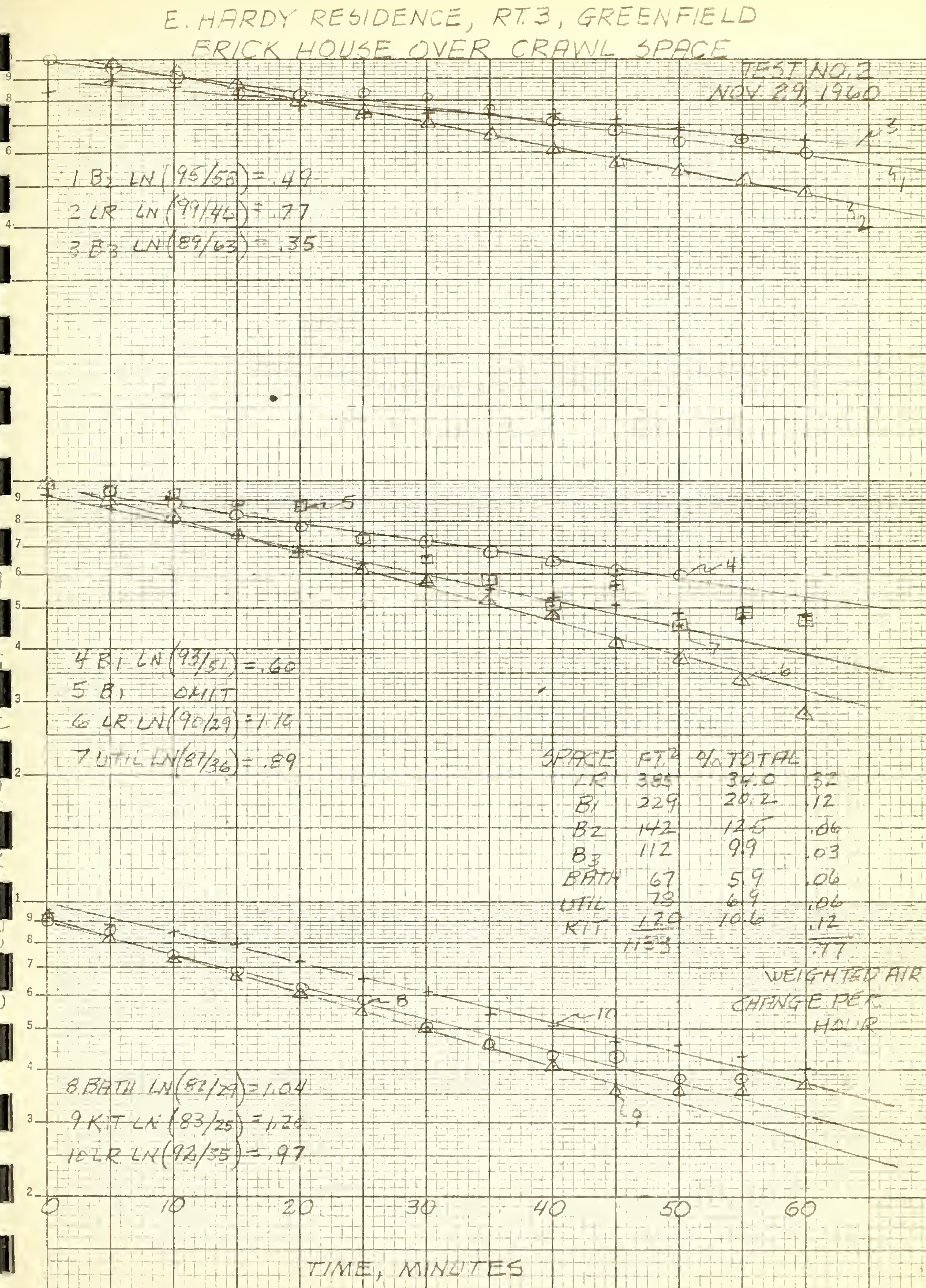
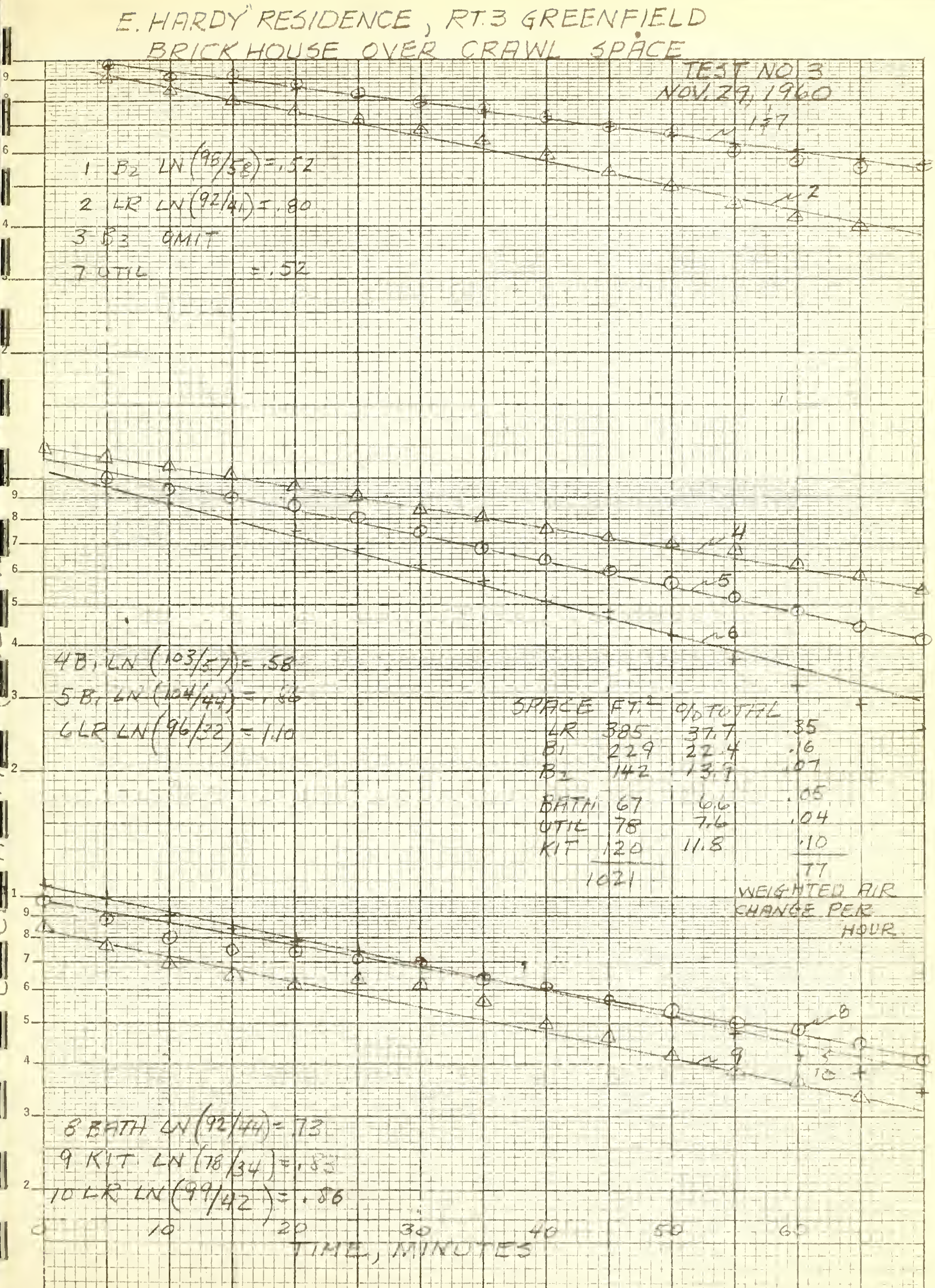

E. HARDY RESIDENCE, RT. 3, GREENFIELD
BRICK HOUSE OVER CRAWL SPACE
TEST NO. 1
NOV. 29, 1960
1 B2 LN(93/52) = .58
2 LR LN(87/39) = .80
3 B3 LN(83/43) = .66
4 B1 LN(95/48) = .68
5 B1 LN(86/35) = .90
6 LR LN(96/34) = 1.04
7 UTIL LN(100/58) = .54
SPACE FT² % TOTAL
LR 385 34.0 .31
B1 229 20.2 .16
B2 142 12.5 .07
B3 112 9.9 .06
BATH 67 5.9 .06
UTIL 78 6.9 .04
KIT 120 10.6 .14
.84
WEIGHTED AIR CHANGE PER HOUR
8 BATH LN(85/30) = 1.04
9 KIT LN(73/20) = 1.30
10 LR OMIT
10
20
30
40
50
60
TIME, MINUTES

Figure 11


E. HARDY RESIDENCE, RT. 3, GREENFIELD
BRICK HOUSE OVER CRAWL SPACE
TEST NO. 2
NOV. 29, 1960
1 B2 LN (95/58) = .49
2 LR LN (99/46) = .77
3 B3 LN (89/63) = .35
4 B1 LN (93/51) = .60
5 B1 OMIT
6 LR LN (90/29) = 1.16
7 UTIL LN (87/36) = .89
SPACE FT.² % TOTAL
LR 385 34.0 .32
B1 229 20.2 .12
B2 142 12.6 .06
B3 112 9.9 .03
BATH 67 5.9 .06
UTIL 78 6.9 .06
KIT 120 10.6 .12
1133 .77
WEIGHTED AIR CHANGE PER HOUR
8 BATH LN (82/29) = 1.04
9 KIT LN (83/25) = 1.26
10 LR LN (92/35) = .97
0 10 20 30 40 50 60
TIME, MINUTES
Figure 12



E. HARDY RESIDENCE, RT.3 GREENFIELD
BRICK HOUSE OVER CRAWL SPACE
TEST NO 3
NOV. 29, 1960
1 B2 LN(95/58) = .52
2 LR LN(92/41) = .80
3 B3 OMIT
7 UTIL = .52
4 B1 LN(103/57) = .58
5 B1 LN(104/44) = .86
6 LR LN(96/32) = 1.10
SPACE FT.2 % TOTAL
LR 385 37.7 .35
B1 229 22.4 .16
B2 142 13.9 .07
BATH 67 6.6 .05
UTIL 78 7.6 .04
KIT 120 11.8 .10
1021
.77
WEIGHTED AIR CHANGE PER HOUR
8 BATH LN(92/44) = .73
9 KIT LN(78/34) = .83
10 LR LN(99/42) = .86
0
10
20
30
40
50
60
TIME, MINUTES

Figure 13

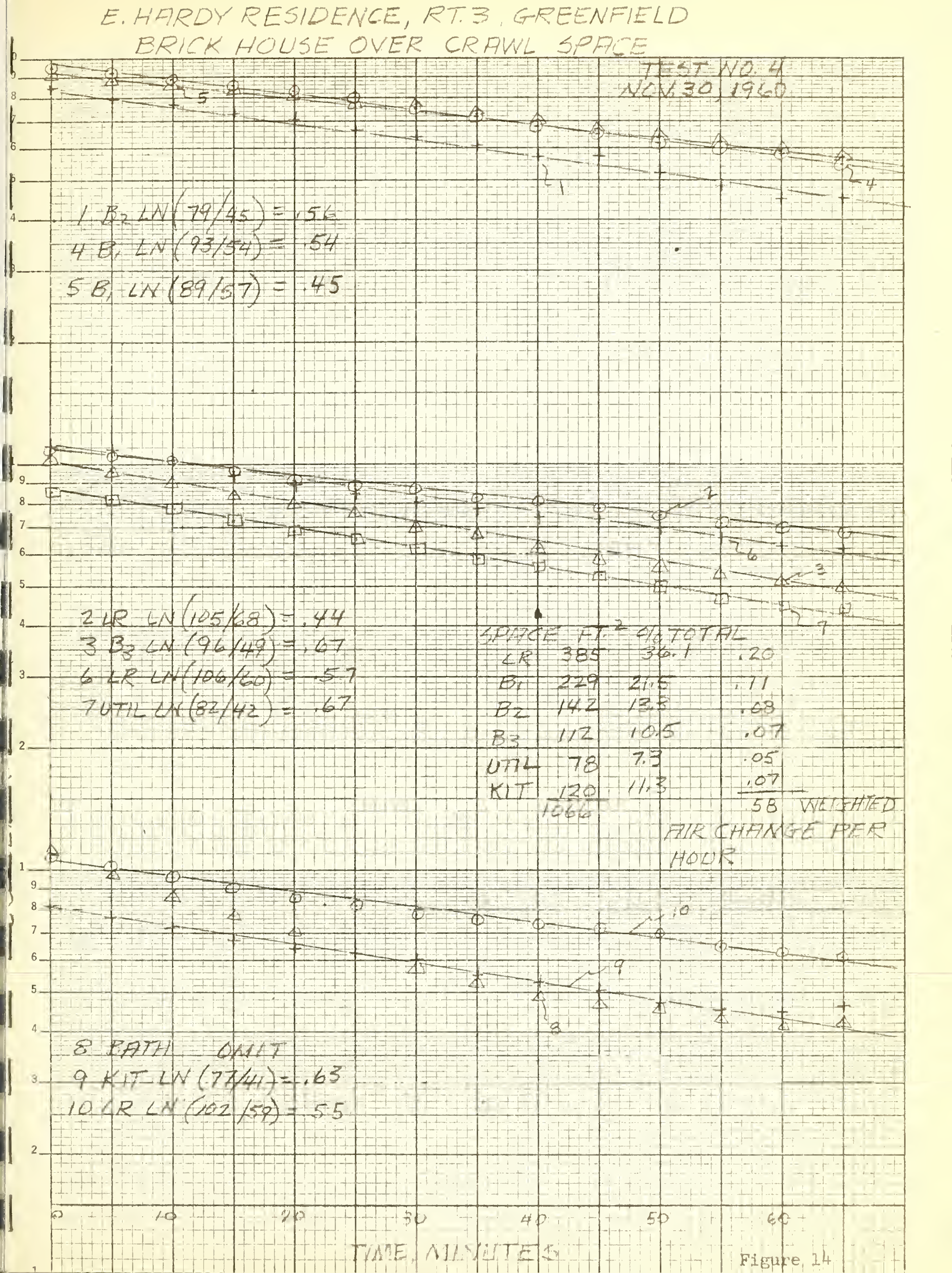

E. HARDY RESIDENCE, RT. 3, GREENFIELD
BRICK HOUSE OVER CRAWL SPACE
TEST NO. 4
NOV. 30, 1960
1 B2 LN (79/45) = .56
4 B1 LN (93/54) = .54
5 B1 LN (89/57) = .45
2 LR LN (105/68) = .44
3 B3 LN (96/49) = .67
6 LR LN (106/60) = .57
7 UTIL LN (82/42) = .67
SPACE FT.2 % TOTAL
LR 385 36.1 .20
B1 229 21.5 .11
B2 142 13.3 .08
B3 112 10.5 .07
UTIL 78 7.3 .05
KIT 120 11.3 .07
1066
.58 WEIGHTED AIR CHANGE PER HOUR
8 BATH OMIT
9 KIT LN (77/41) = .63
10 LR LN (102/59) = .55
0
10
20
30
40
50
60
TIME, MINUTES

Figure 14

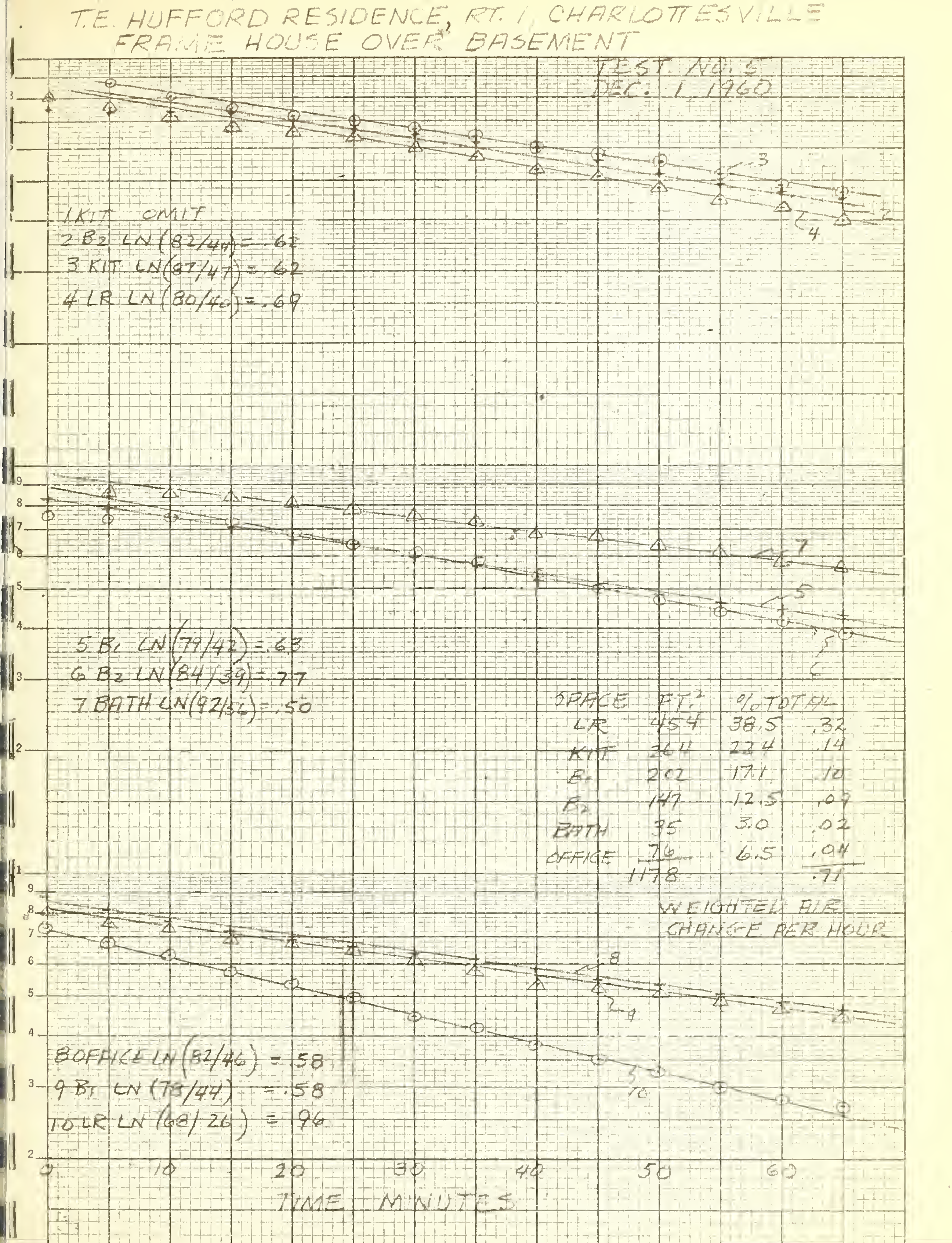

T.E. HUFFORD RESIDENCE, RT. 1 CHARLOTTESVILLE
FRAME HOUSE OVER BASEMENT
TEST No. 5
DEC. 1, 1960
1 KIT OMIT
2 B2 LN (82/44) = .62
3 KIT LN (87/47) = .62
4 LR LN (80/40) = .69
5 B1 LN (79/42) = .63
6 B2 LN (84/39) = .77
7 BATH LN (92/56) = .50
SPACE FT.2 % TOTAL
LR 454 38.5 .32
KIT 264 22.4 .14
B1 202 17.1 .10
B2 147 12.5 .09
BATH 35 3.0 .02
OFFICE 76 6.5 .04
1178 .71
WEIGHTED AIR CHANGE PER HOUR
8 OFFICE LN (82/46) = .58
9 B1 LN (78/44) = .58
10 LR LN (68/26) = .96
0 10 20 30 40 50 60
TIME MINUTES

Figure 15

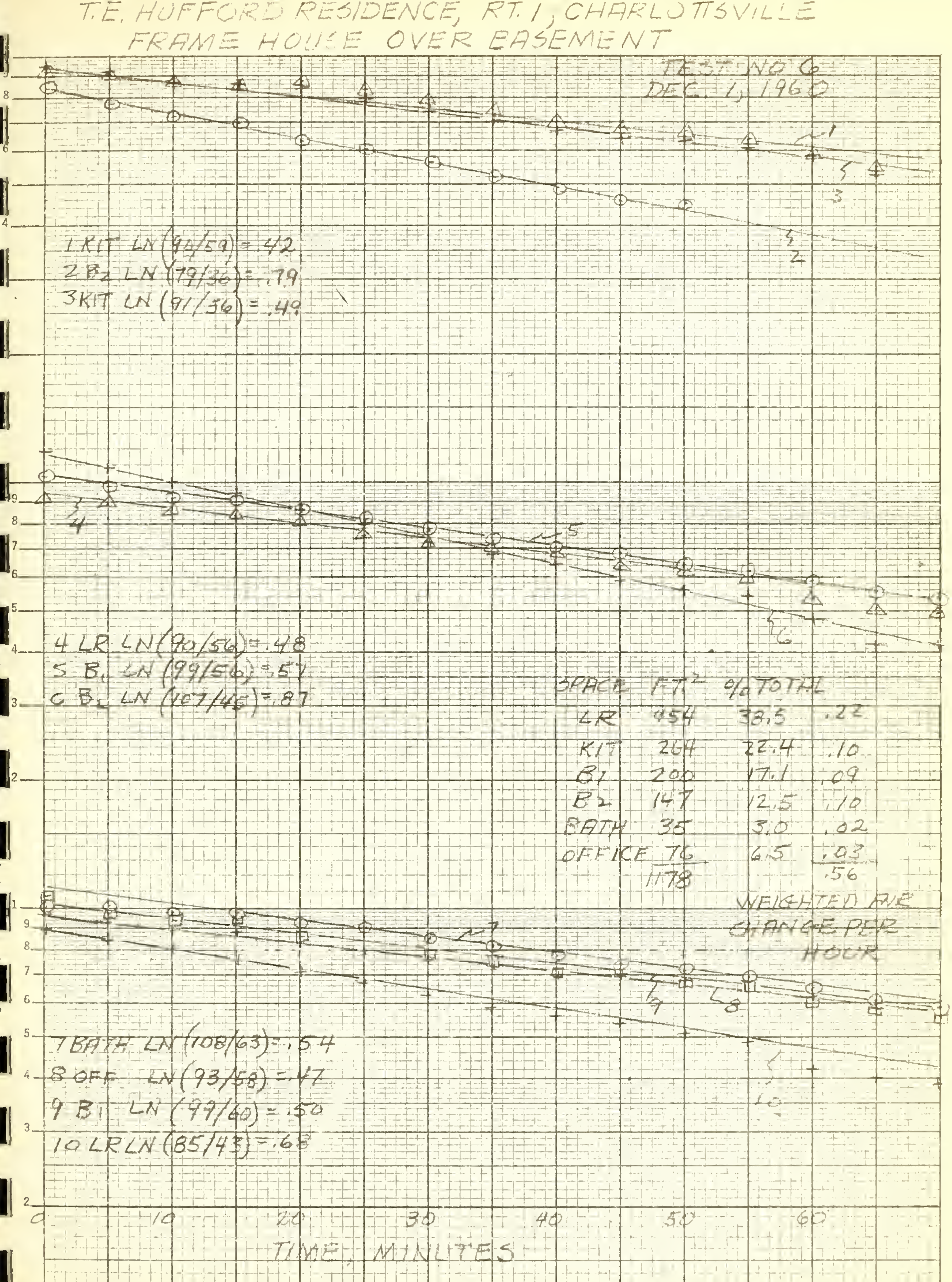

T.E. HUFFORD RESIDENCE, RT. 1, CHARLOTTSVILLE
FRAME HOUSE OVER BASEMENT
TEST NO 6
DEC. 1, 1960
1 KIT LN (90/59) = .42
2 B2 LN (79/36) = .79
3 KIT LN (91/56) = .49
4 LR LN (90/56) = .48
5 B1 LN (99/56) = .57
6 B2 LN (107/45) = .87
SPACE FT² % TOTAL
LR 454 38.5 .22
KIT 264 22.4 .10
B1 200 17.1 .09
B2 147 12.5 .10
BATH 35 3.0 .02
OFFICE 76 6.5 .03
1178 .56
WEIGHTED AIR CHANGE PER HOUR
7 BATH LN (108/63) = .54
8 OFF LN (93/58) = .47
9 B1 LN (99/60) = .50
10 LR LN (85/43) = .68
0 10 20 30 40 50 60
TIME, MINUTES

Figure 16

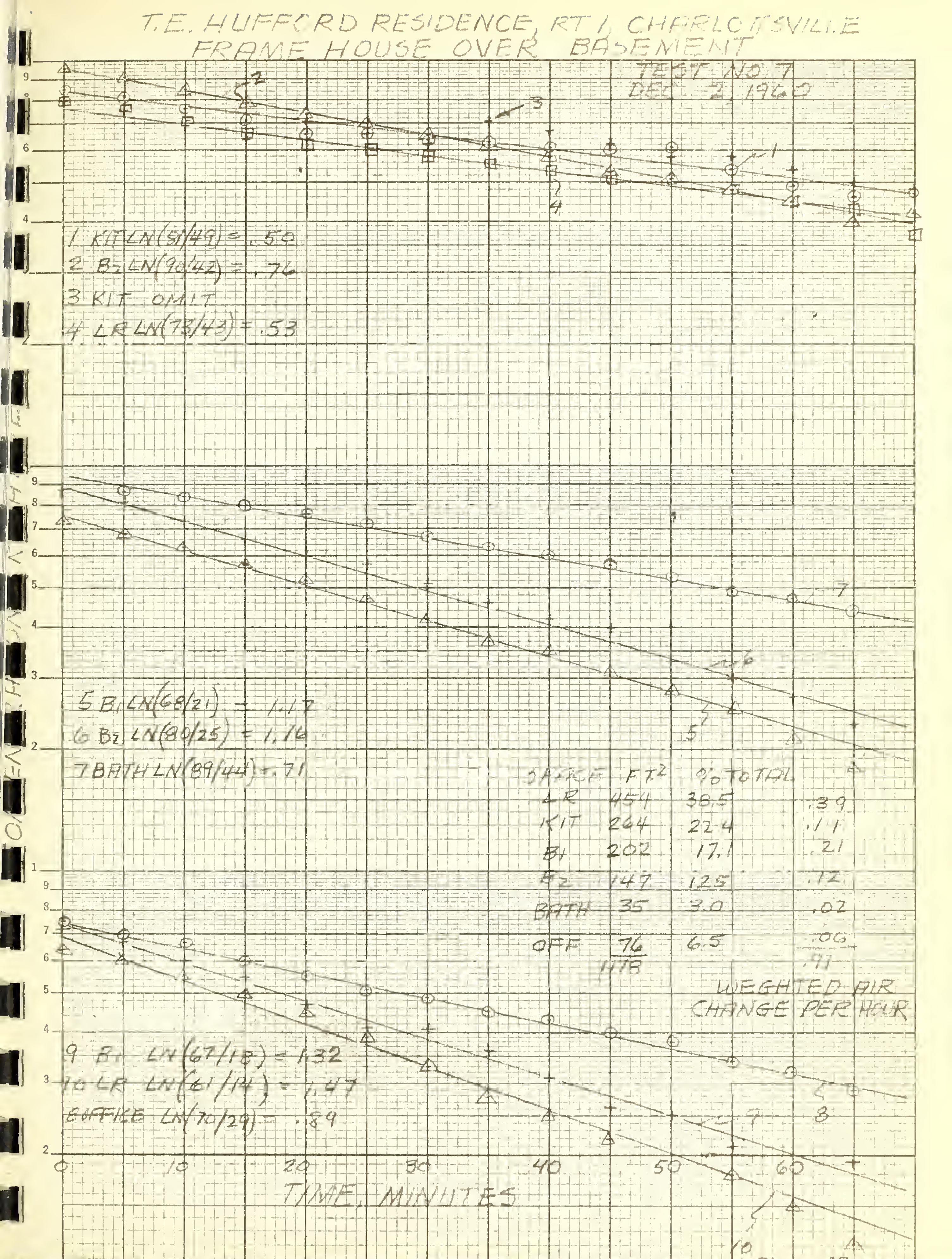

T.E. HUFFORD RESIDENCE, RT 1, CHARLOTTSVILLE
FRAME HOUSE OVER BASEMENT
TEST NO. 7
DEC. 2, 1969
1 KIT LN(51/49) = .50
2 B2 LN(98/42) = .76
3 KIT OMIT
4 LR LN(73/43) = .53
5 B1 LN(68/21) = 1.17
6 B2 LN(80/25) = 1.16
7 BATH LN(89/44) = .71
SPACE FT2 % TOTAL
LR 454 38.5 .39
KIT 264 22.4 .11
B1 202 17.1 .21
B2 147 12.5 .12
BATH 35 3.0 .02
OFF 76 6.5 .06
1178 .91
WEIGHTED AIR CHANGE PER HOUR
9 B1 LN(67/18) = 1.32
10 LR LN(61/14) = 1.47
OFFICE LN(70/29) = .89
TIME, MINUTES
0 10 20 30 40 50 60

Figure 17

J. S. CRAIG RESIDENCE, RR. 1, WABASH

BRICK HOUSE WITH BASEMENT AND CRAWL SPACE

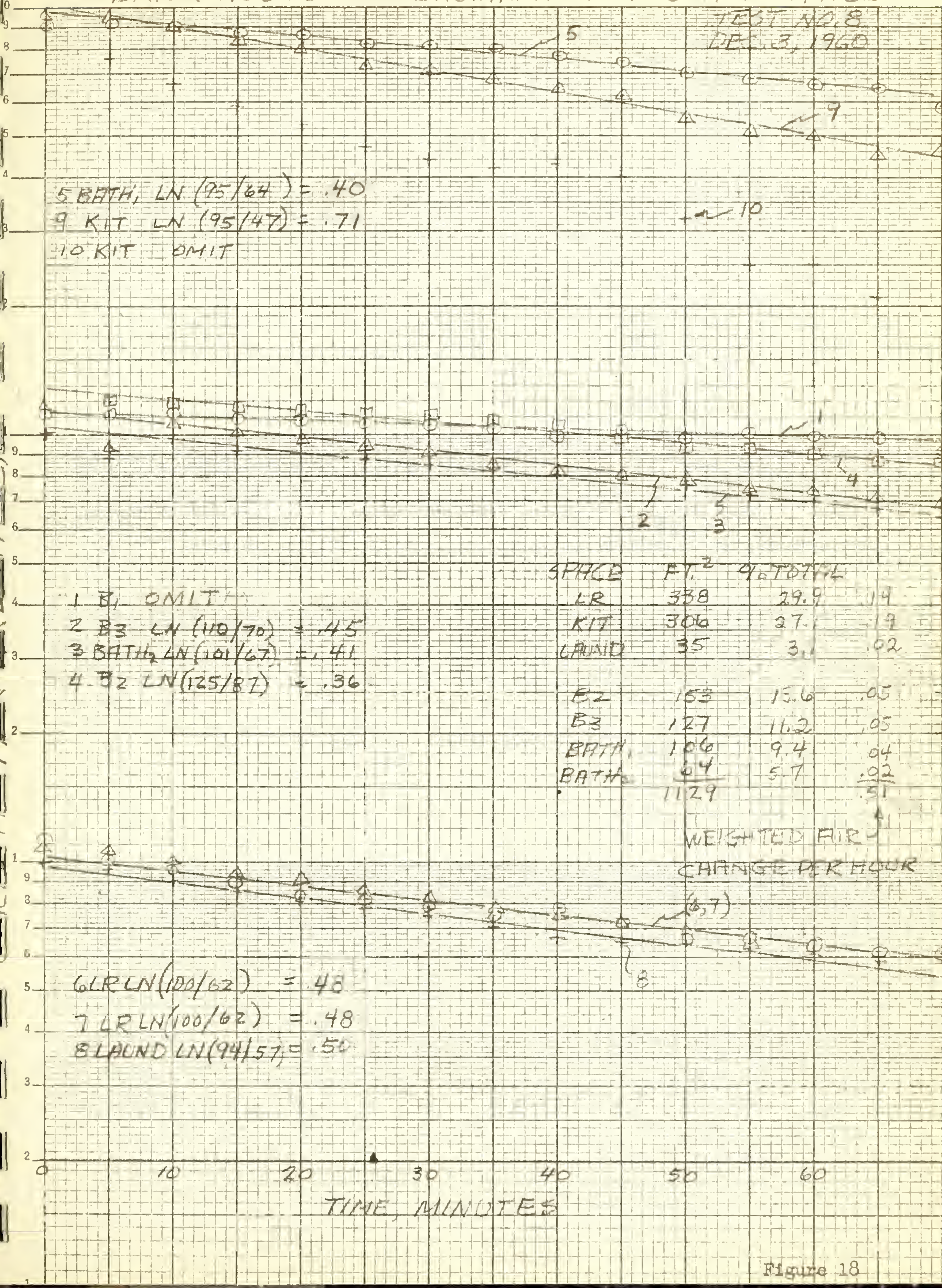


Figure 18

J.S. CRAIG RESIDENCE, RR.1, WABASH

BRICK HOUSE WITH BASEMENT AND CRAWL SPACE

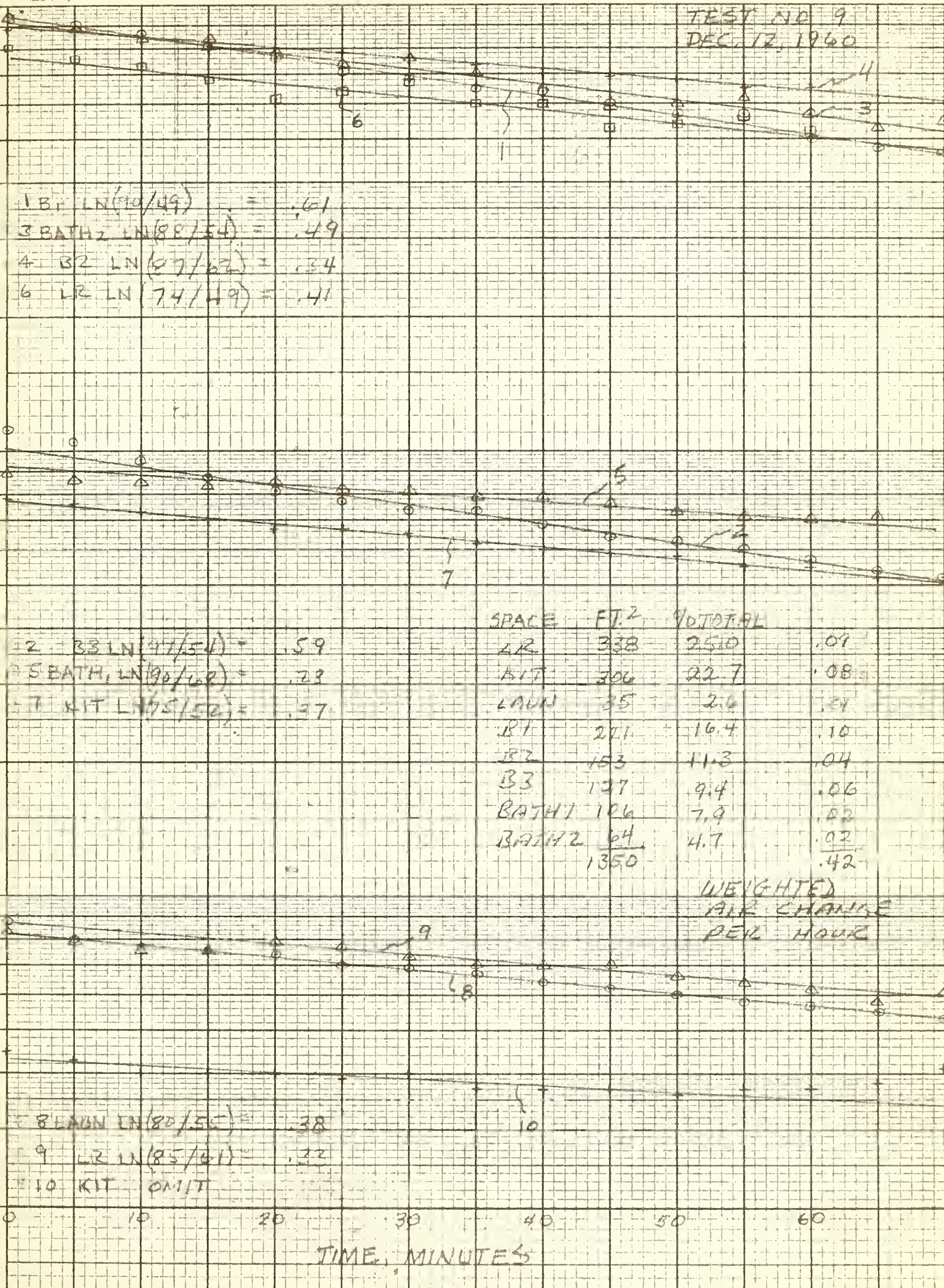


Figure 19

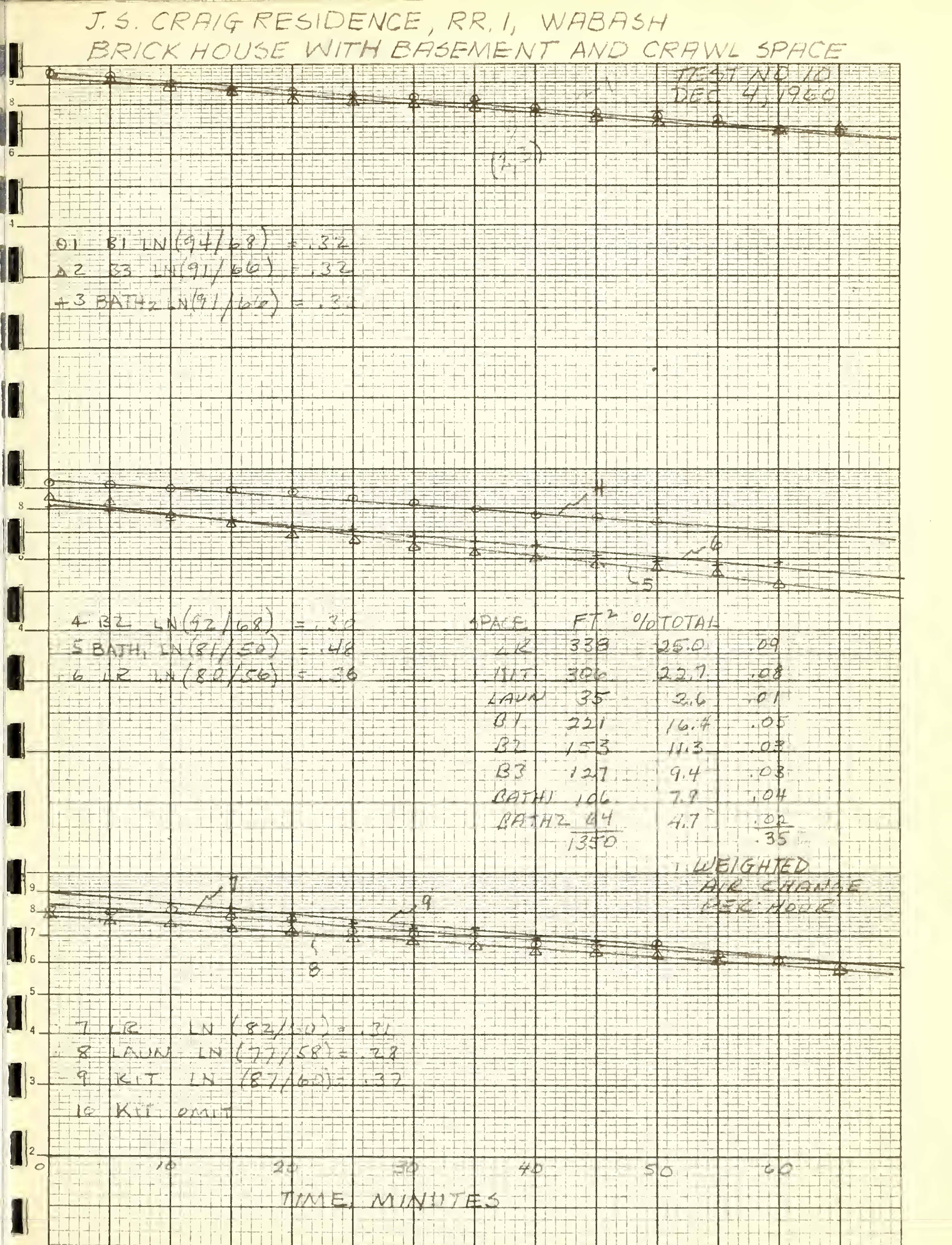

J. S. CRAIG RESIDENCE, RR. 1, WABASH
BRICK HOUSE WITH BASEMENT AND CRAWL SPACE
TEST NO 10
DEC 4, 1960
○1 B1 LN(94/68) = .32
△2 B3 LN(91/66) = .32
+3 BATH2 LN(91/66) = .32
4 B2 LN(92/68) = .30
5 BATH1 LN(81/50) = .48
6 LR LN(80/56) = .36
SPACE FT² % TOTAL
LR 338 25.0 .09
KIT 306 22.7 .08
LAUN 35 2.6 .01
B1 221 16.4 .05
B2 153 11.3 .03
B3 127 9.4 .03
BATH1 106 7.9 .04
BATH2 64 4.7 .02
1350 .35
WEIGHTED AIR CHANGE PER HOUR
7 LR LN (82/60) = .31
8 LAUN LN (77/58) = .28
9 KIT LN (87/60) = .37
10 KIT omit
0 10 20 30 40 50 60
TIME, MINUTES

Figure 20

D.A. METZGER RESIDENCE, RR.3, N. MANCHESTER
FRAME HOUSE WITH BASEMENT AND CRAWL SPACE

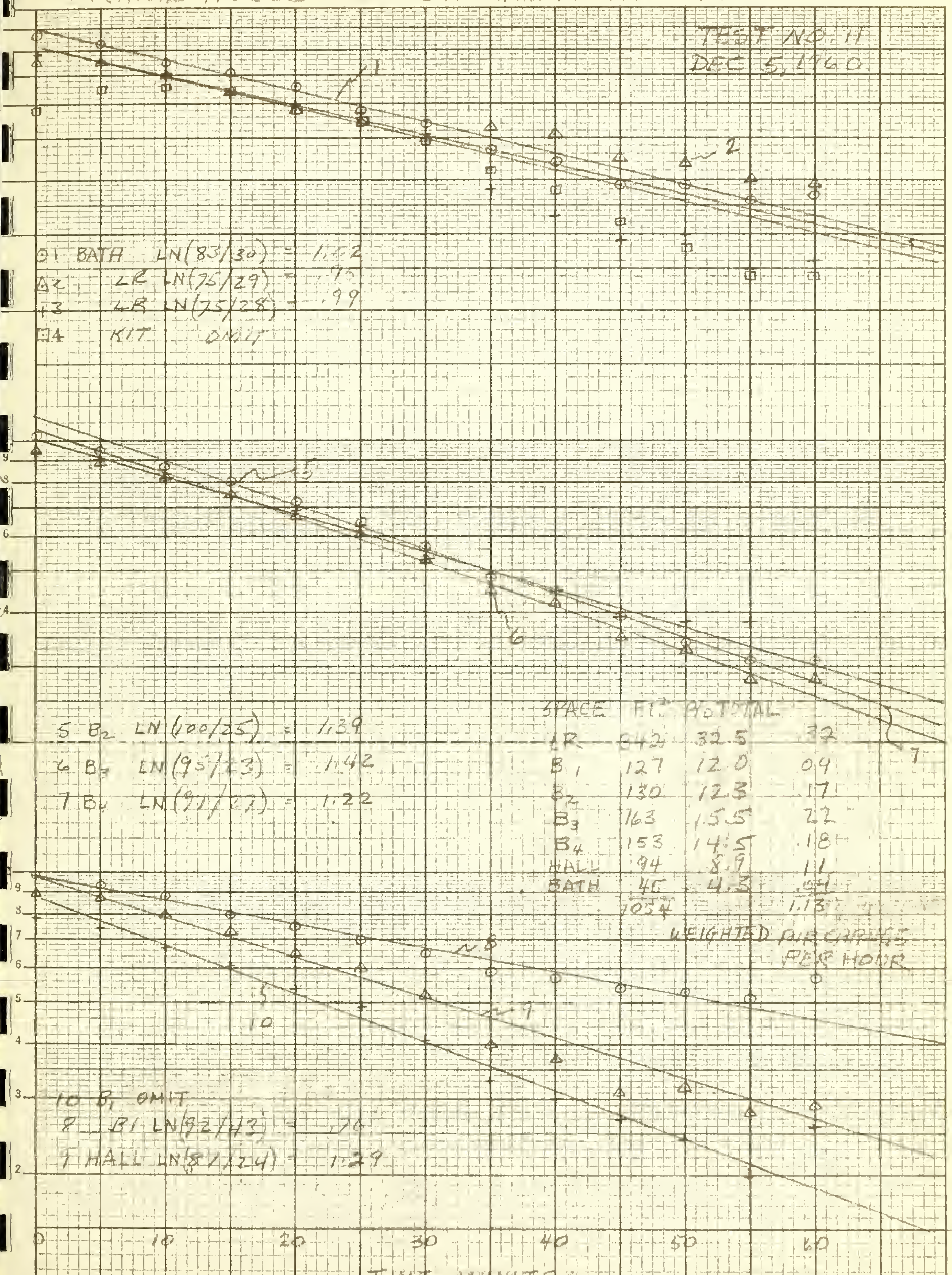


Figure 21

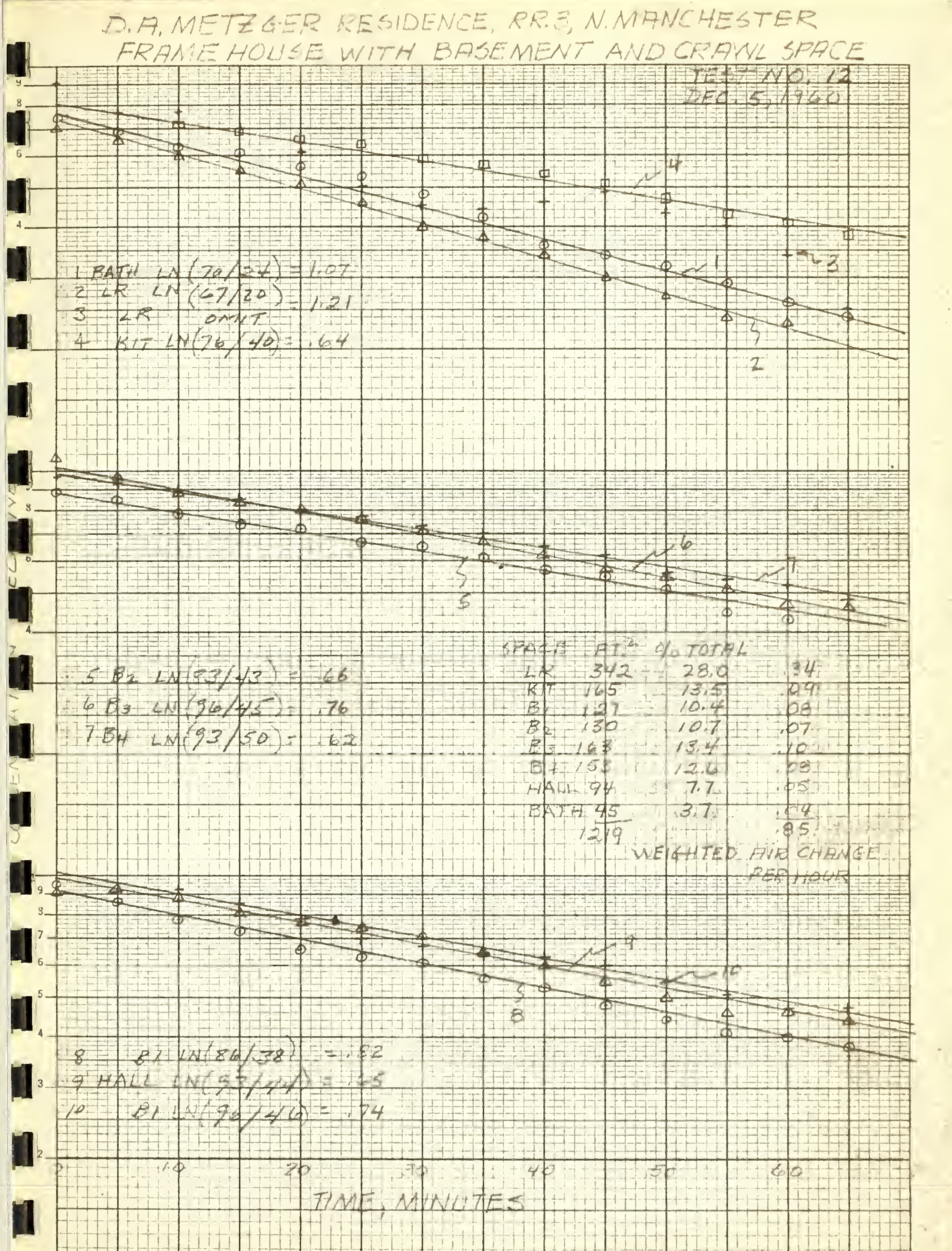

D.A. METZGER RESIDENCE, RR.3, N. MANCHESTER
FRAME HOUSE WITH BASEMENT AND CRAWL SPACE
TEST NO. 12
DEC. 5, 1960
1 BATH LN(70/24) = 1.07
2 LR LN(67/20) = 1.21
3 LR OMNT
4 KIT LN(76/40) = .64
5 B2 LN(93/43) = .66
6 B3 LN(96/45) = .76
7 B4 LN(93/50) = .62
SPACE FT.² % TOTAL
LR 342 28.0 .34
KIT 165 13.5 .09
B1 127 10.4 .08
B2 130 10.7 .07
B3 163 13.4 .10
B4 153 12.6 .08
HALL 94 7.7 .05
BATH 45 3.7 .04
1219 .85
WEIGHTED AIR CHANGE PER HOUR
8 B1 LN(86/38) = .82
9 HALL LN(97/44) = .65
10 B1 LN(96/46) = .74
TIME, MINUTES

Figure 22

D.A. METZGER RESIDENCE, RR3, N. MANCHESTER
FRAME HOUSE WITH BASEMENT AND CRAWL SPACE

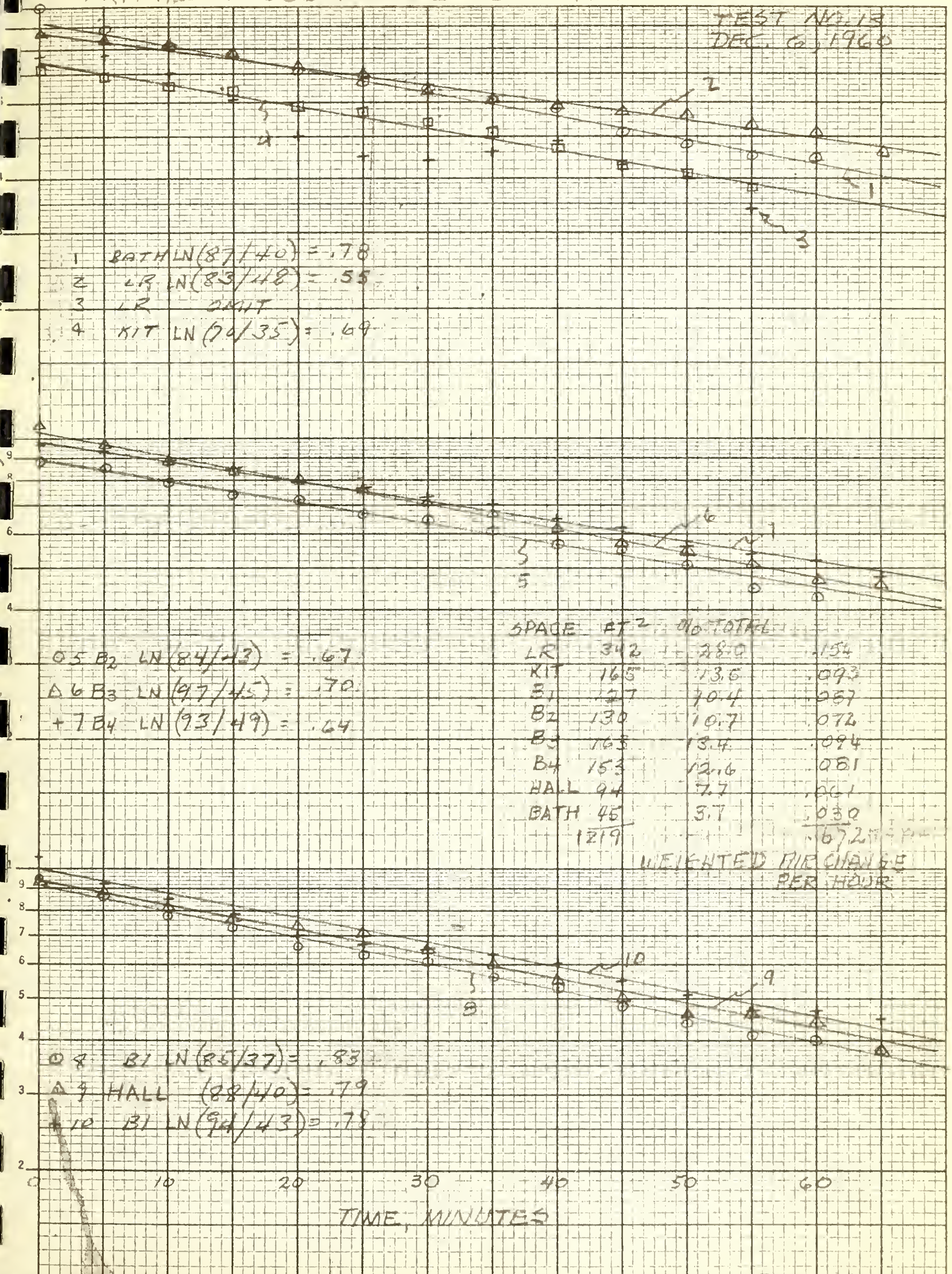


Figure 23

R. WRIGLEY RESIDENCE, R.R. 3, WARSAW
FRAME HOUSE OVER BASEMENT

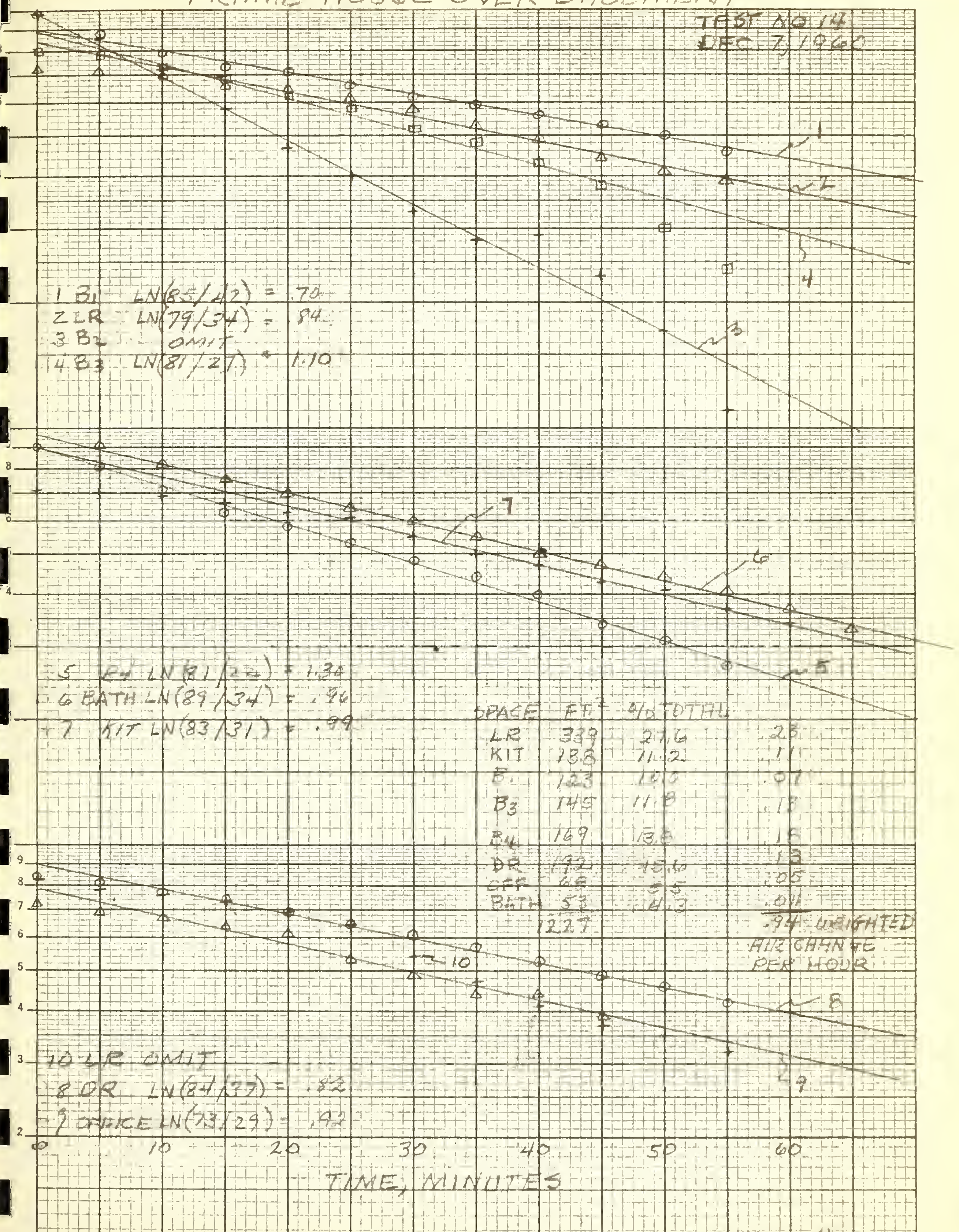


Figure 24

R. WRIGLEY RESIDENCE, RR.3, WARSAW
FRAME HOUSE OVER BASEMENT

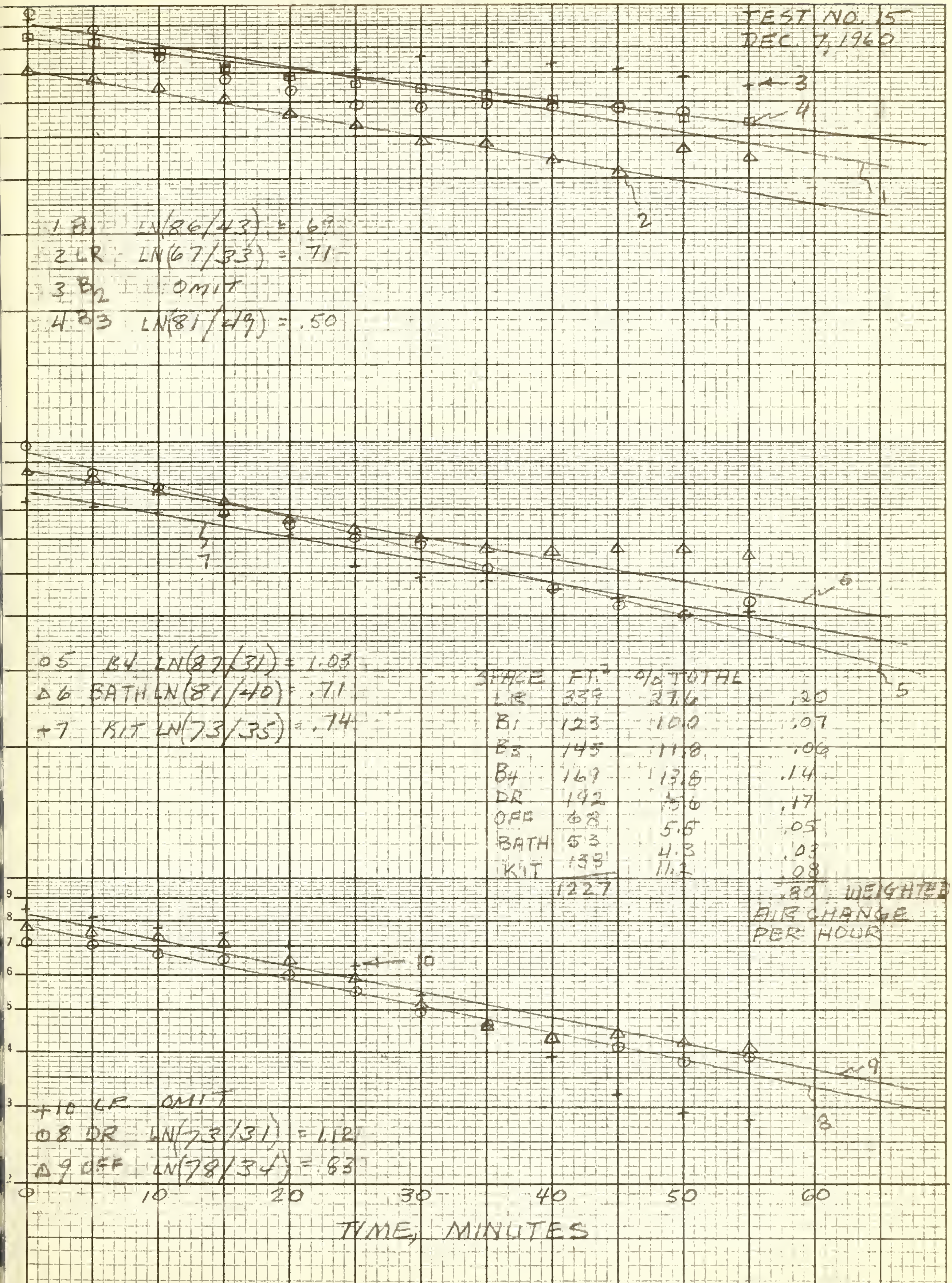


Figure 25

R. WRIGLEY RESIDENCE, RR.3, WARSAW
FRAME HOUSE OVER BASEMENT

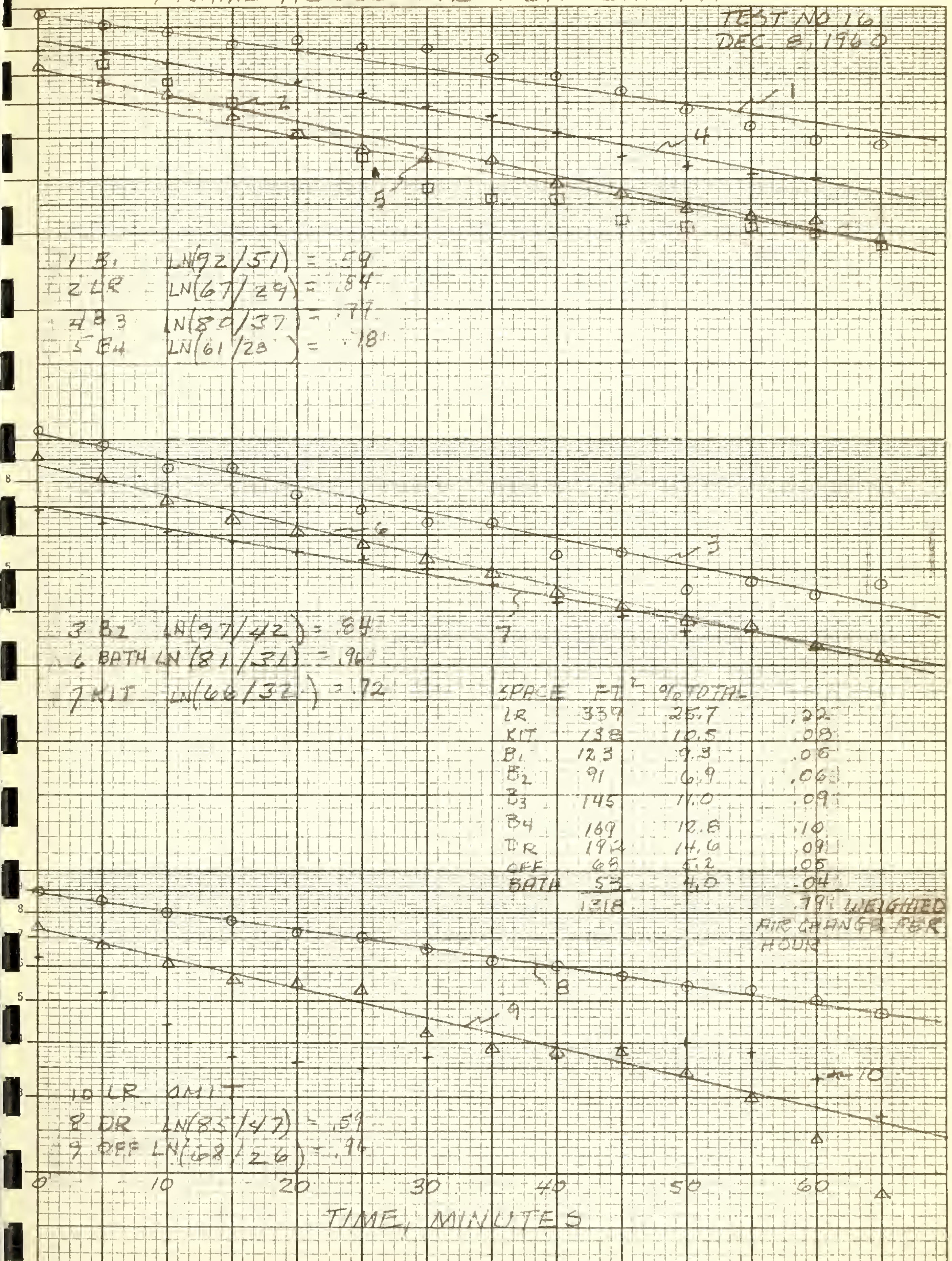
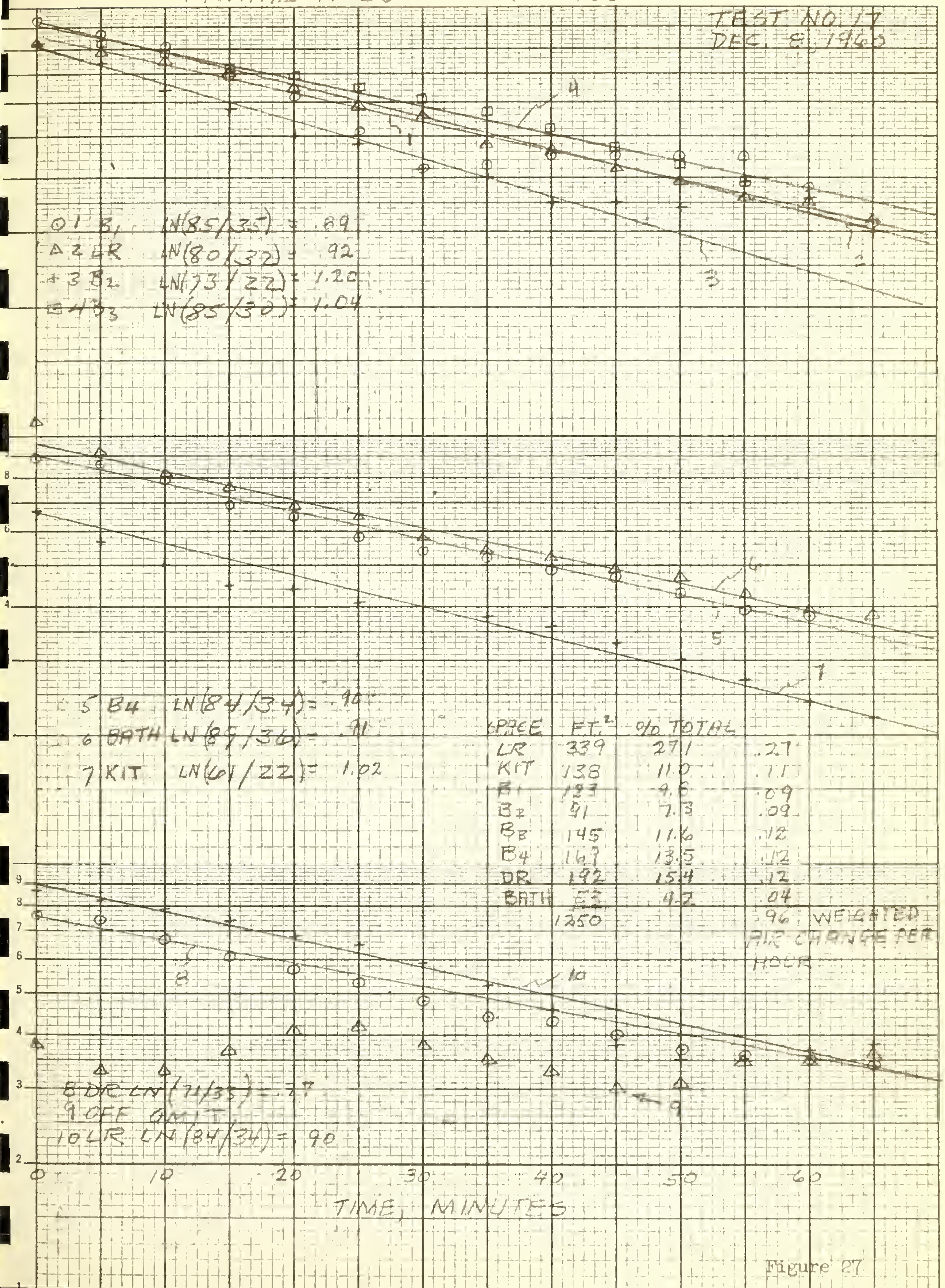


Figure 26

R. WRIGLEY RESIDENCE, RR. 3, WARSAW
FRAME HOUSE OVER BASEMENT



SPACE	FT²	% TOTAL	
LR	339	27.1	.27
KIT	138	11.0	.11
B1	123	9.8	.09
B2	91	7.3	.09
B3	145	11.6	.12
B4	169	13.5	.12
DR	192	15.4	.12
BATH	53	4.2	.04
	1250		.96 WEIGHTED AIR CHANGE PER HOUR

Figure 27

TEST NO. 18
DEC. 7, 1960

M. SPANN RESIDENCE

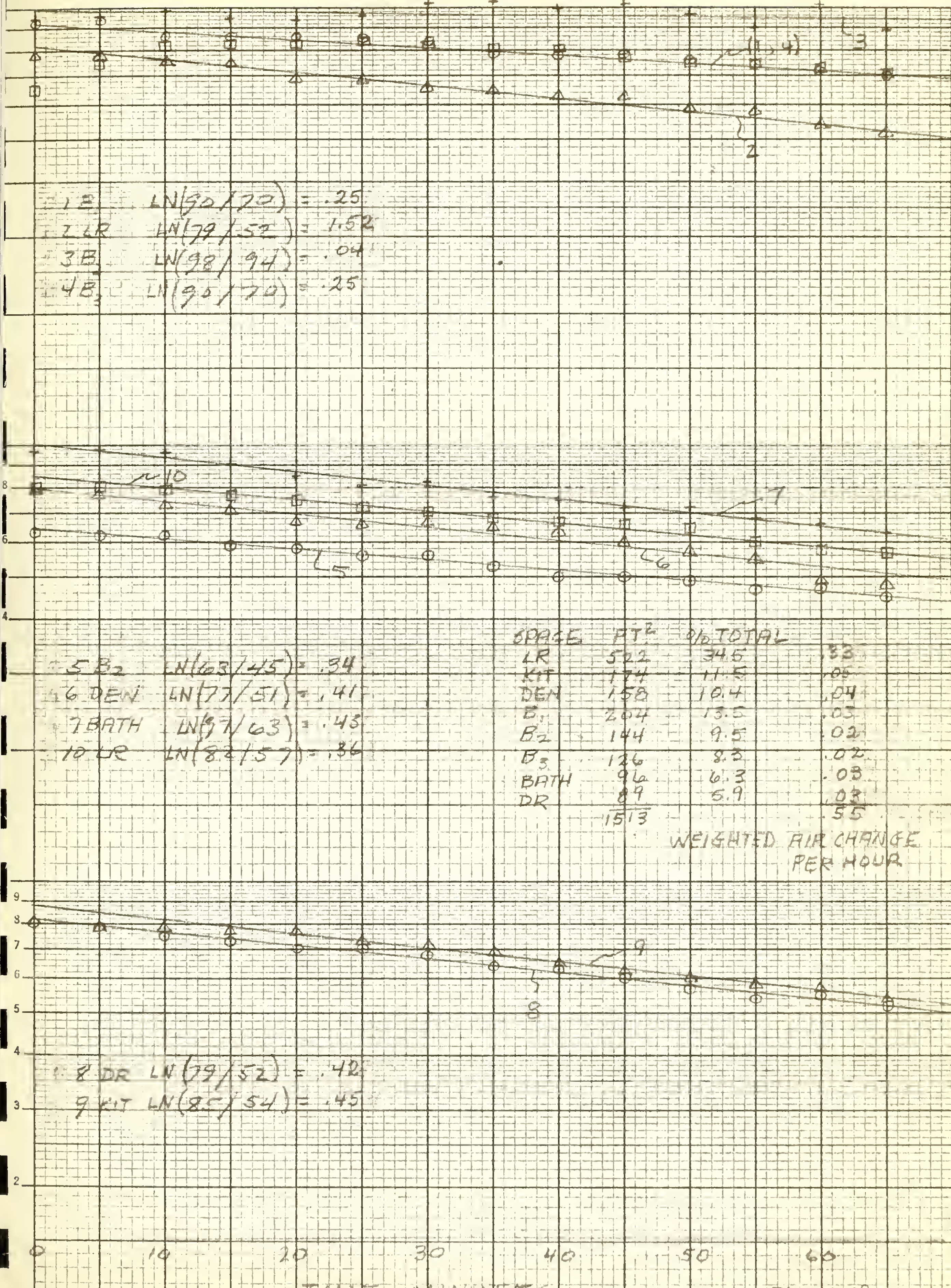


Figure 28

TEST NO. 19
DEC. 9, 1960

M. SPANN RESIDENCE

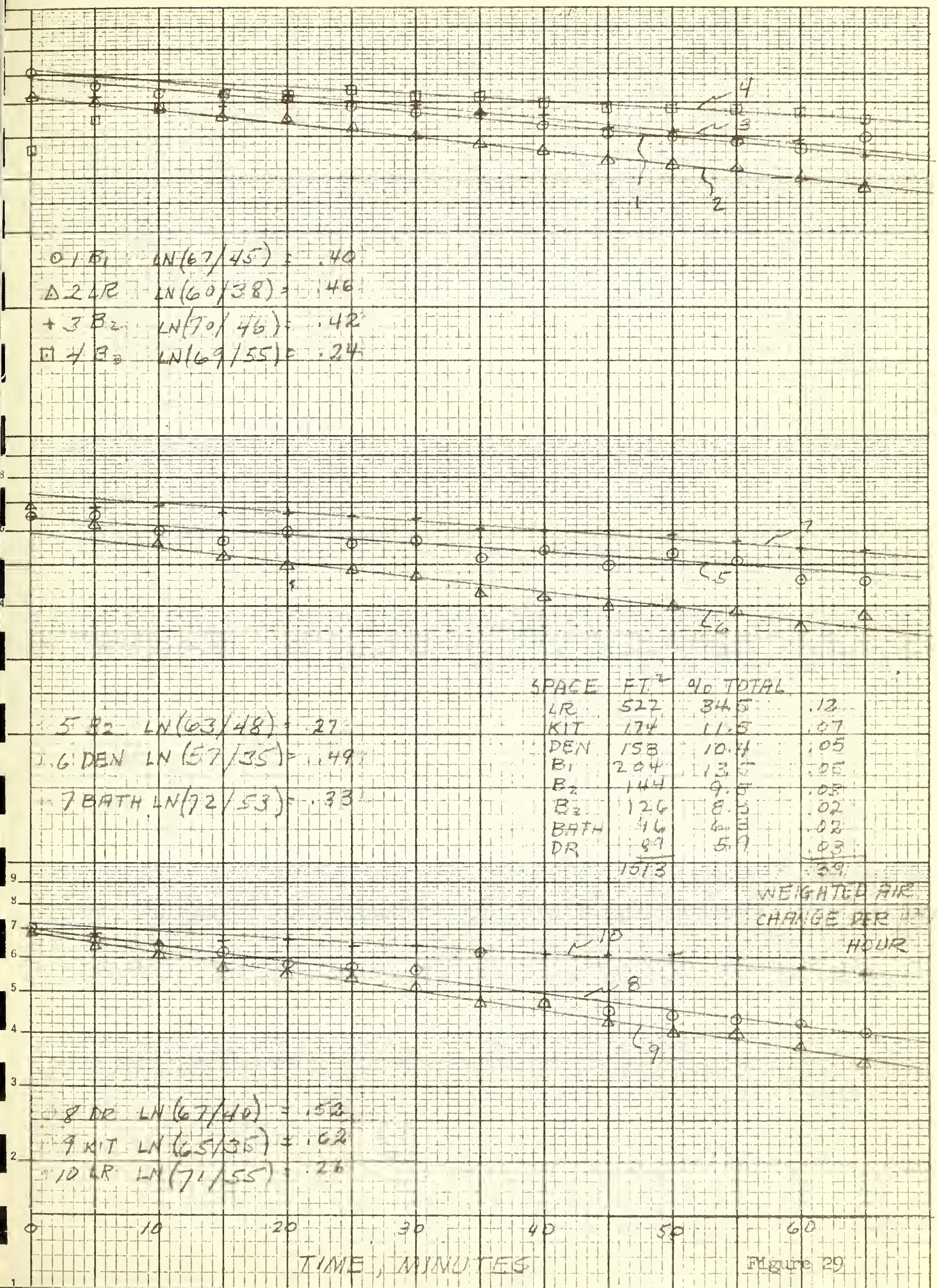


Figure 29

TEST NO. 20
DEC. 10, 1960

M. SPANN RESIDENCE

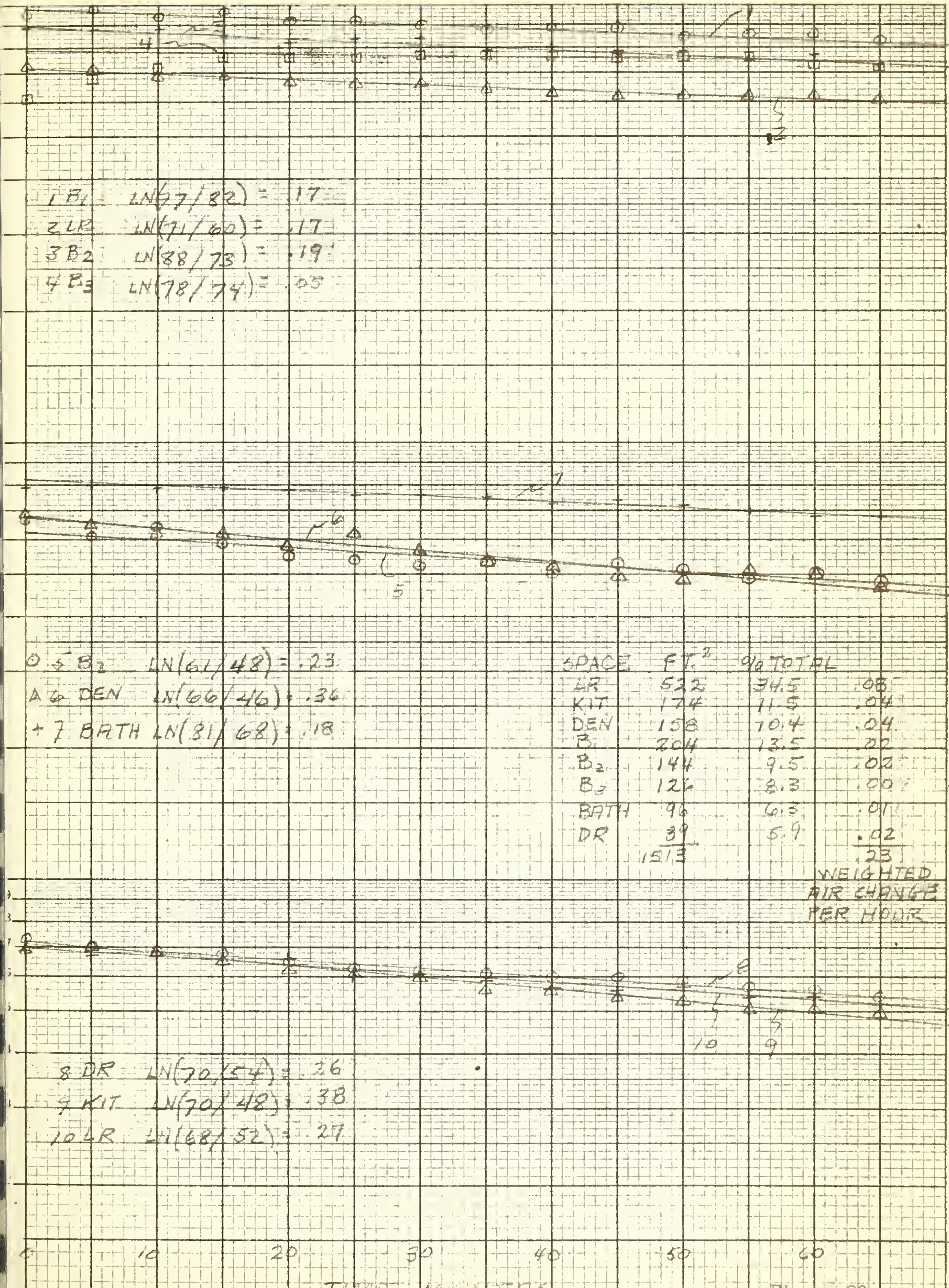


Figure 30

B. YEITER RESIDENCE

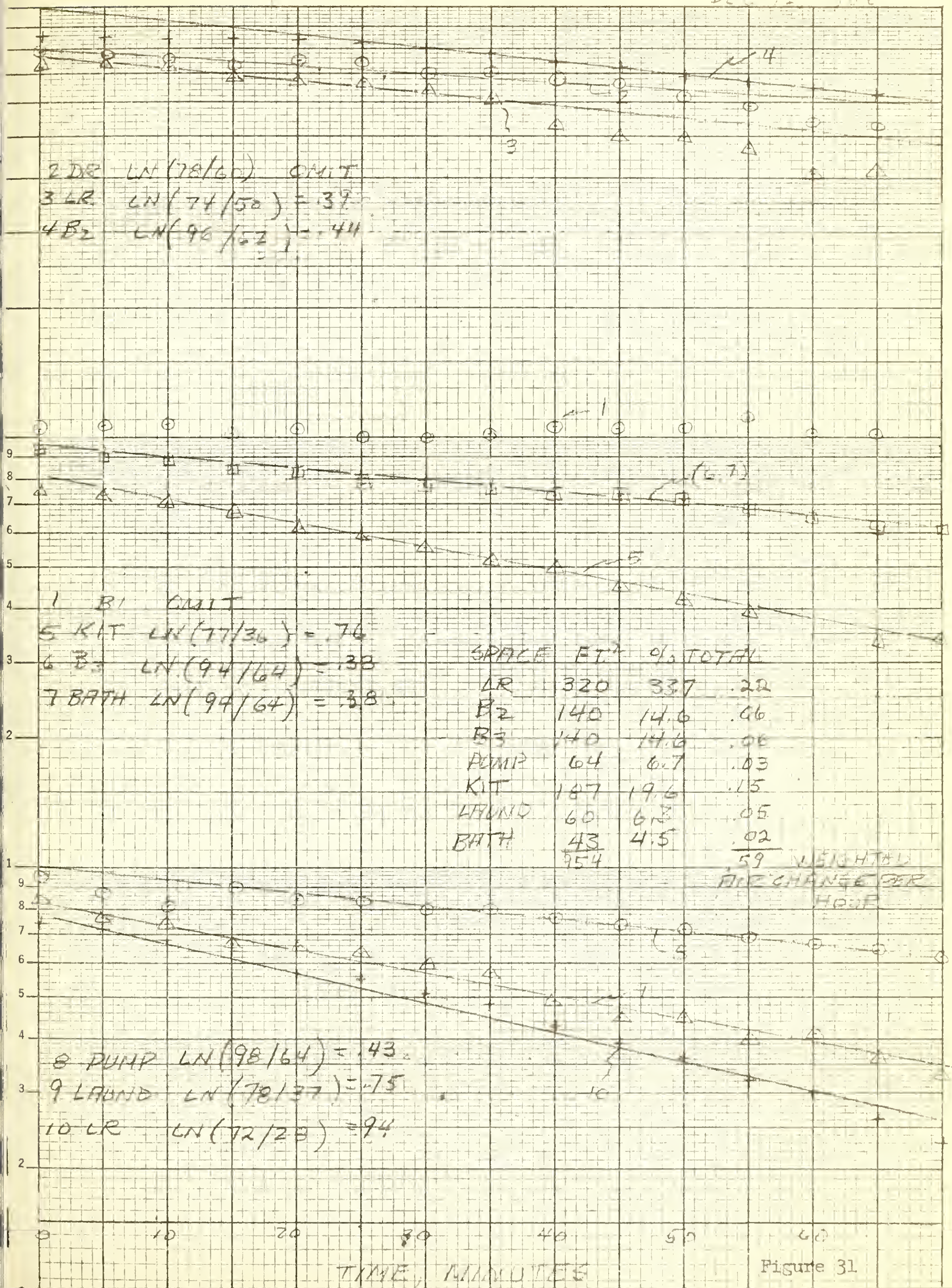


Figure 31

B. YEITER RESIDENCE

TEST NO. 22
DEC. 13, 1960

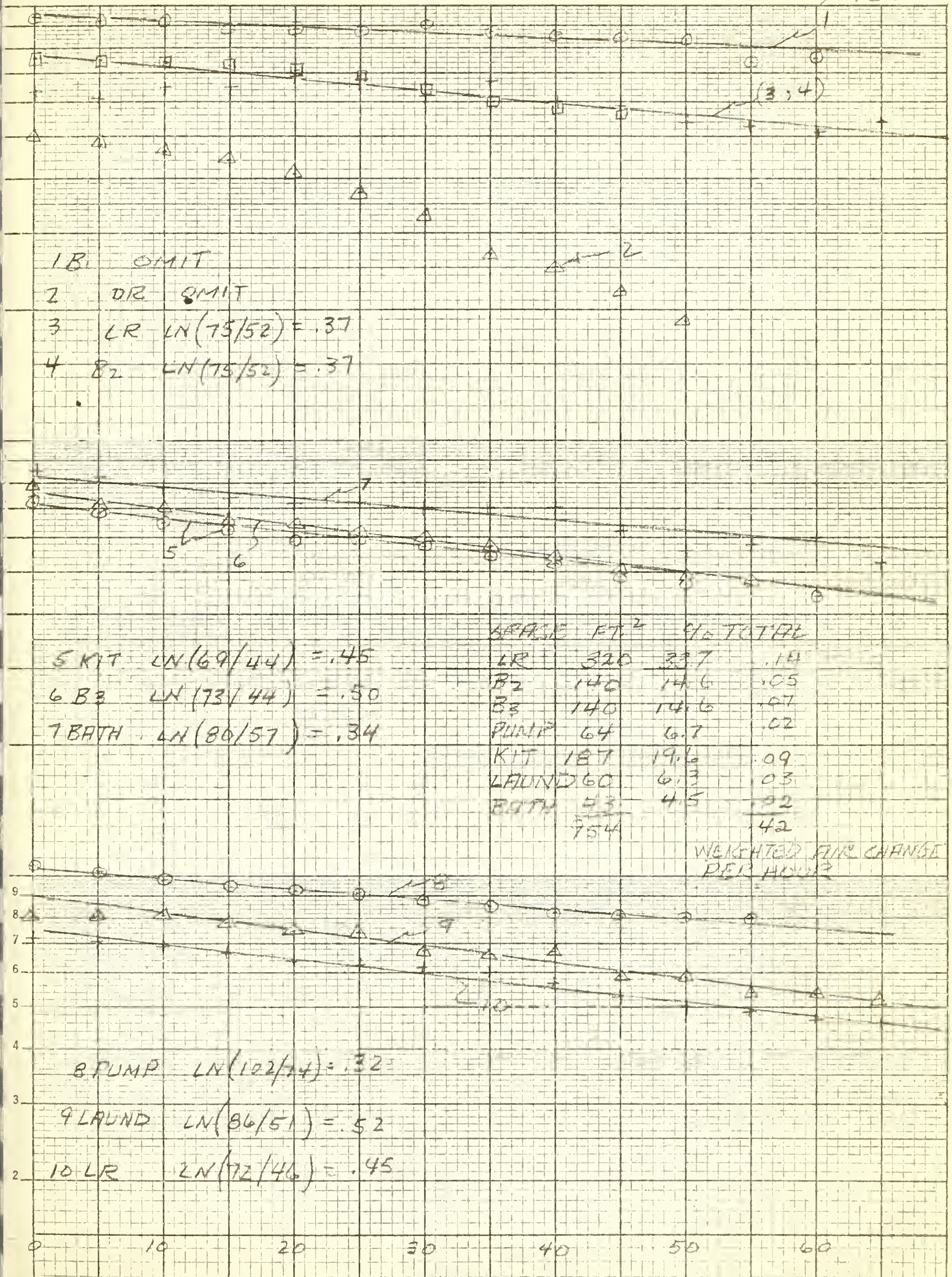


Figure 32

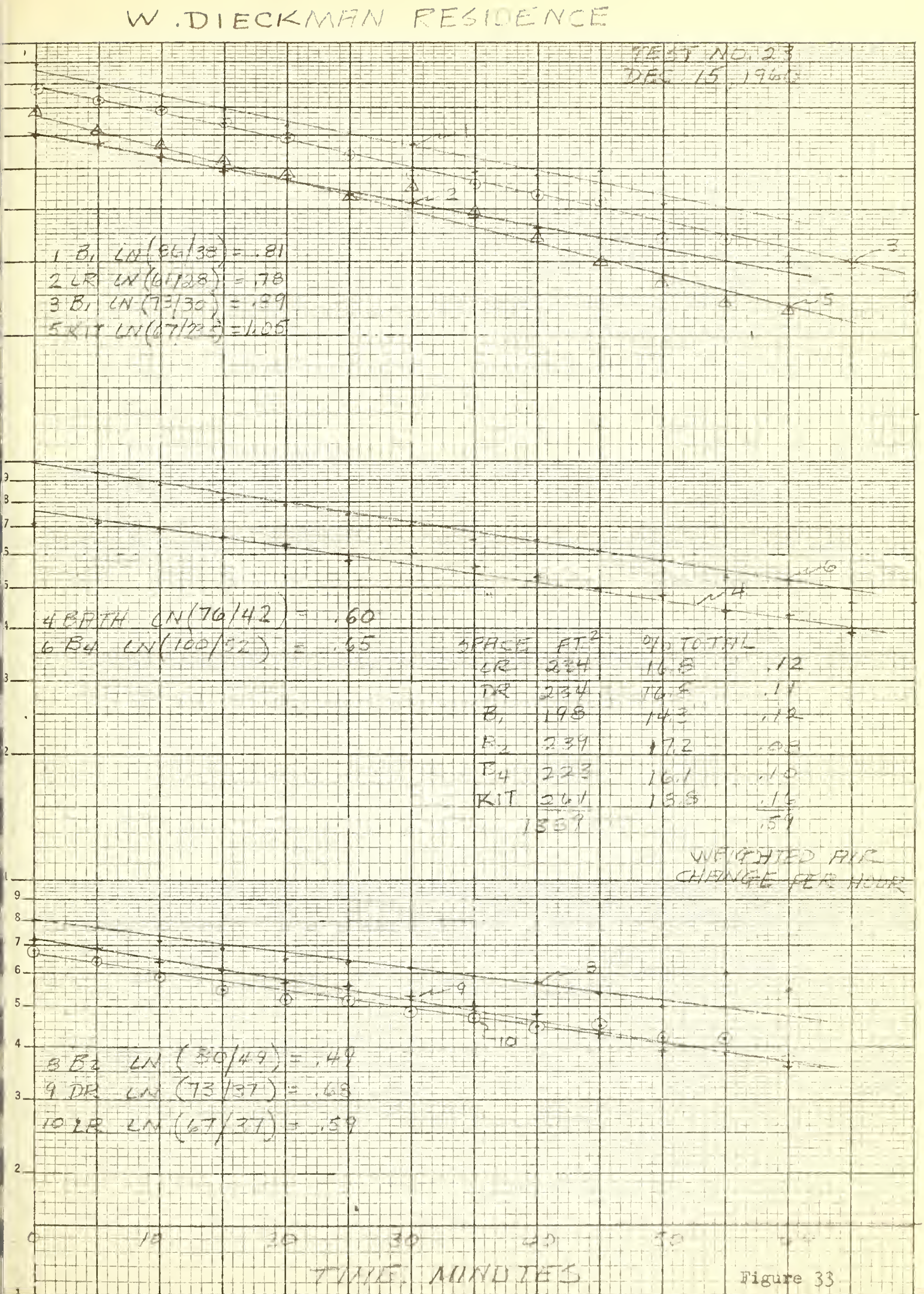

W. DIECKMAN RESIDENCE
TEST NO. 23
1 B1 LN(86/38) = .81
2 LR LN(61/28) = .78
3 B1 LN(73/30) = .89
5 KIT LN(67/23) = 1.05
4 BATH LN(76/42) = .60
6 B4 LN(100/52) = .65
SPACE FT² % TOTAL
LR 234 16.8 .12
DR 234 16.8 .11
B1 198 14.3 .12
B2 239 17.2 .08
B4 223 16.1 .10
KIT 261 18.8 .16
1389 .59
WEIGHTED AIR CHANGE PER HOUR
8 B2 LN(80/49) = .49
9 DR LN(73/37) = .68
10 LR LN(67/37) = .59
0
10
20
30
40
50
TIME, MINUTES

Figure 33

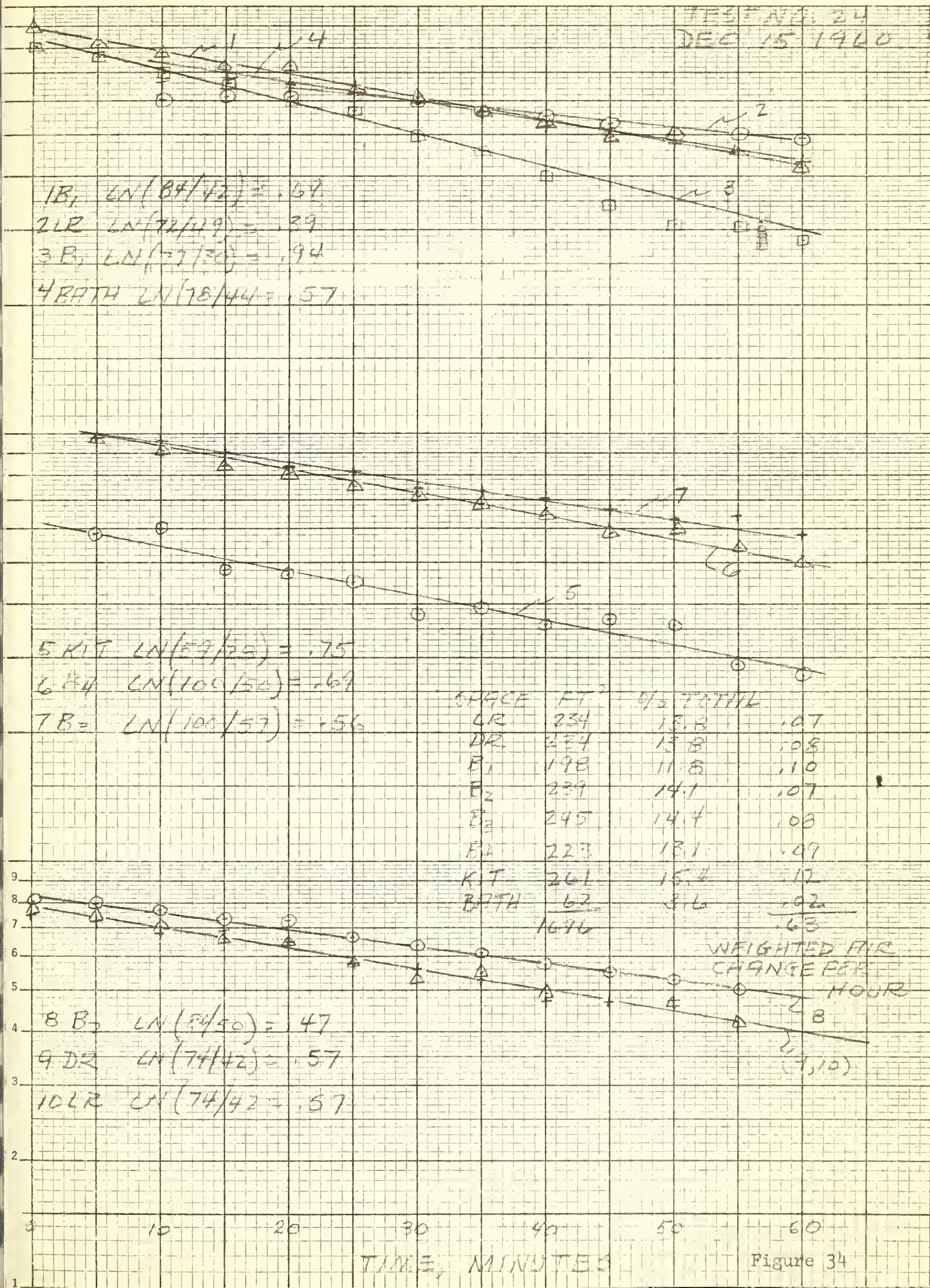

TEST NO. 24
DEC 15 1980
1B1 LN(84/42) = .69
2LR LN(72/49) = .39
3B1 LN(77/30) = .94
4BATH LN(78/44) = .57
5KIT LN(59/28) = .75
6B4 LN(100/50) = .69
7B3 LN(100/57) = .56
SPACE FT² % TOTAL
LR 234 13.8 .07
DR 234 13.8 .08
B1 198 11.8 .10
B2 239 14.1 .07
B3 245 14.4 .08
B4 223 13.1 .09
KIT 261 15.4 .12
BATH 62 3.6 .02
1646 .63
WEIGHTED AIR CHANGE PER HOUR
8 B2 LN(84/50) = .47
9 DR LN(74/42) = .57
10LR LN(74/42) = .57
(9,10)
TIME, MINUTES

Figure 34

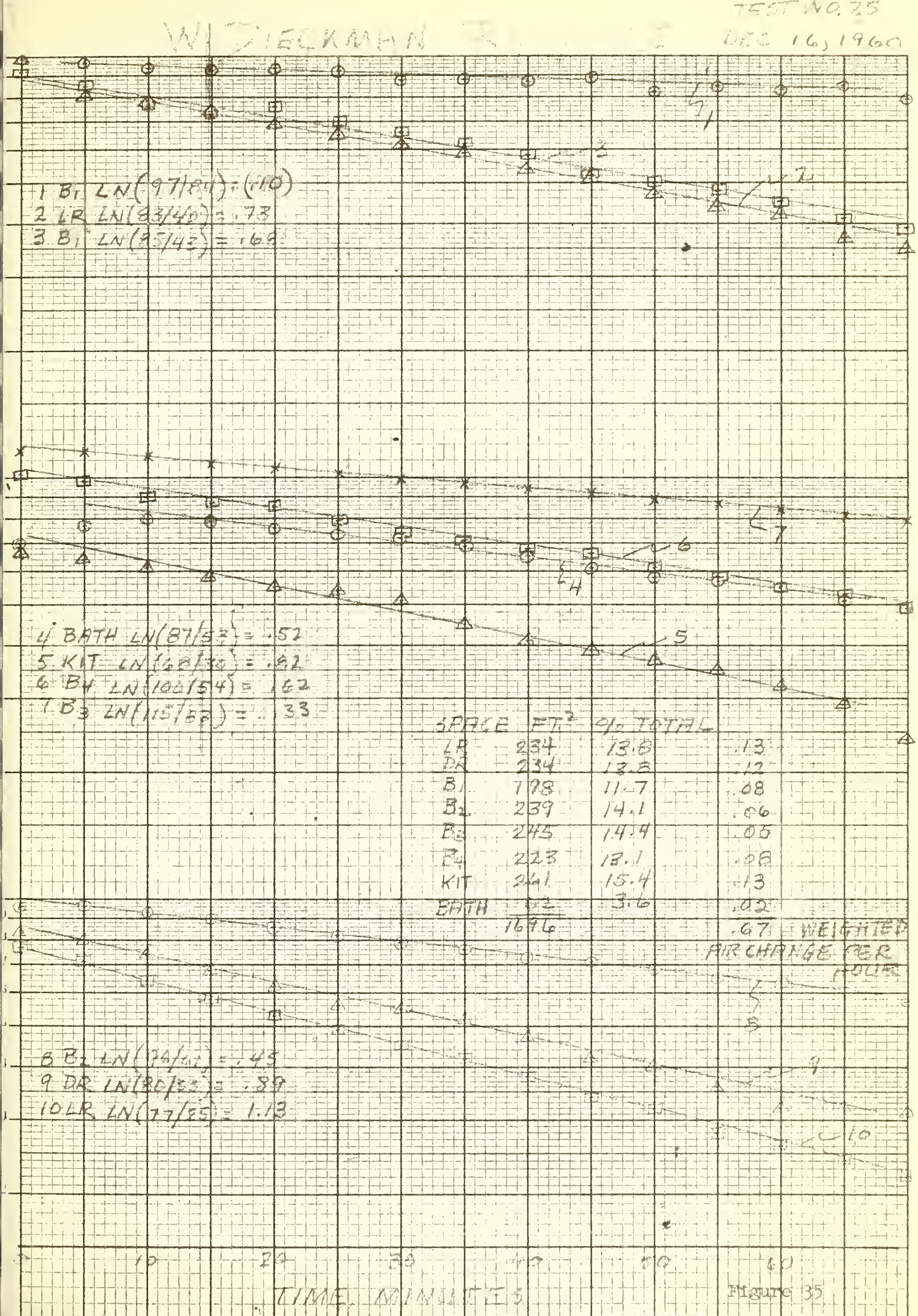

TEST NO. 35
DEC 16, 1960
1 B1 LN(97/84) = (.10)
2 LR LN(83/40) = .73
3 B1 LN(95/43) = .69
4 BATH LN(87/53) = .52
5 KIT LN(68/30) = .82
6 B4 LN(100/54) = .62
7 B3 LN(115/83) = .33
SPACE FT² % TOTAL
LR 234 13.8 .13
DR 234 13.8 .12
B1 198 11.7 .08
B2 239 14.1 .06
B3 245 14.4 .05
B4 223 13.1 .08
KIT 261 15.4 .13
BATH 62 3.6 .02
1696 .67 WEIGHTED AIR CHANGE PER HOUR
8 B2 LN(84/61) = .45
9 DR LN(80/33) = .89
10 LR LN(77/25) = 1.13
10
20
30
40
50
60
TIME, MINUTES

Figure 35

C. FARNSLEY

TEST NO. 27
DEC. 17, 196-

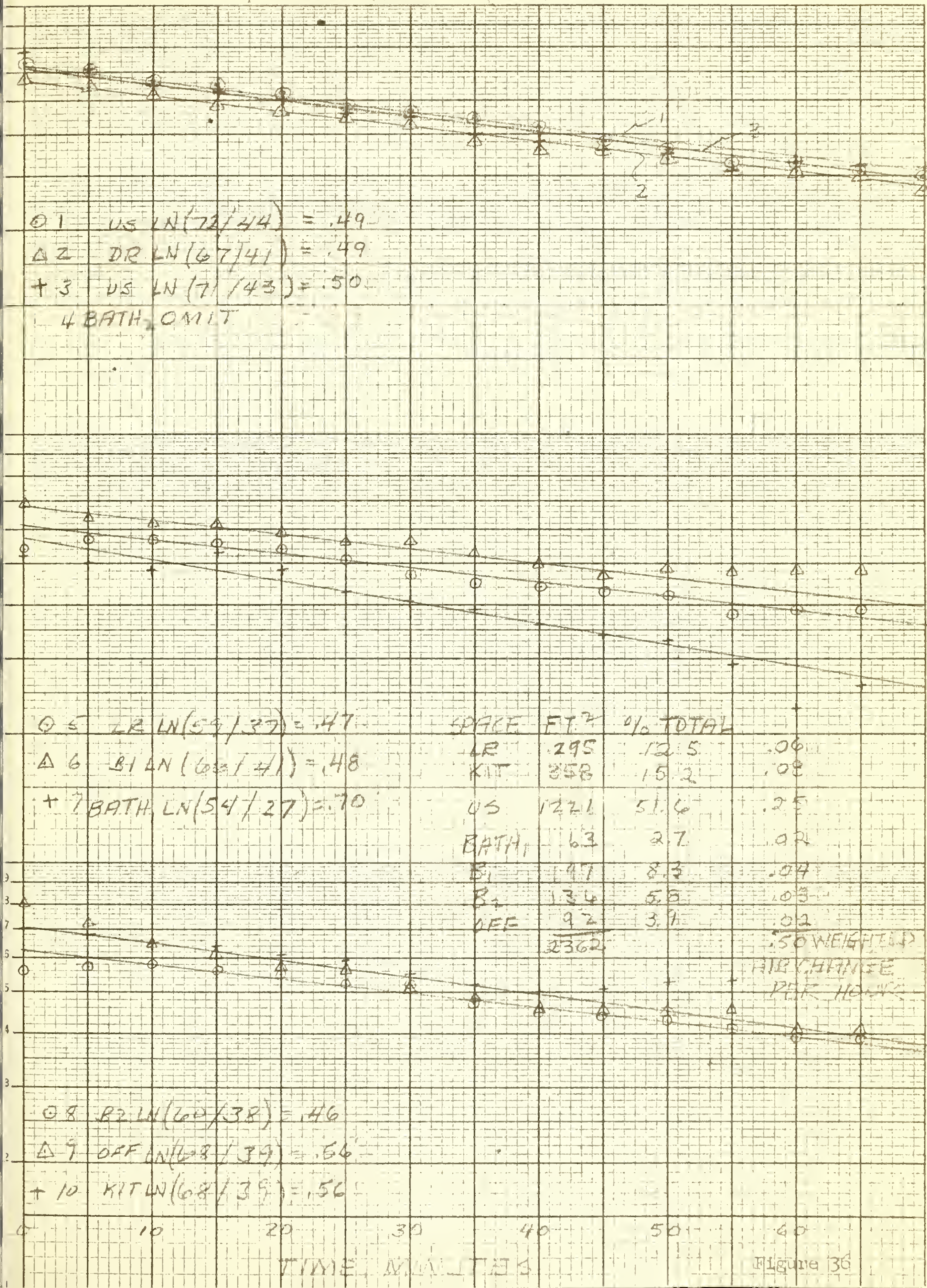


Figure 36

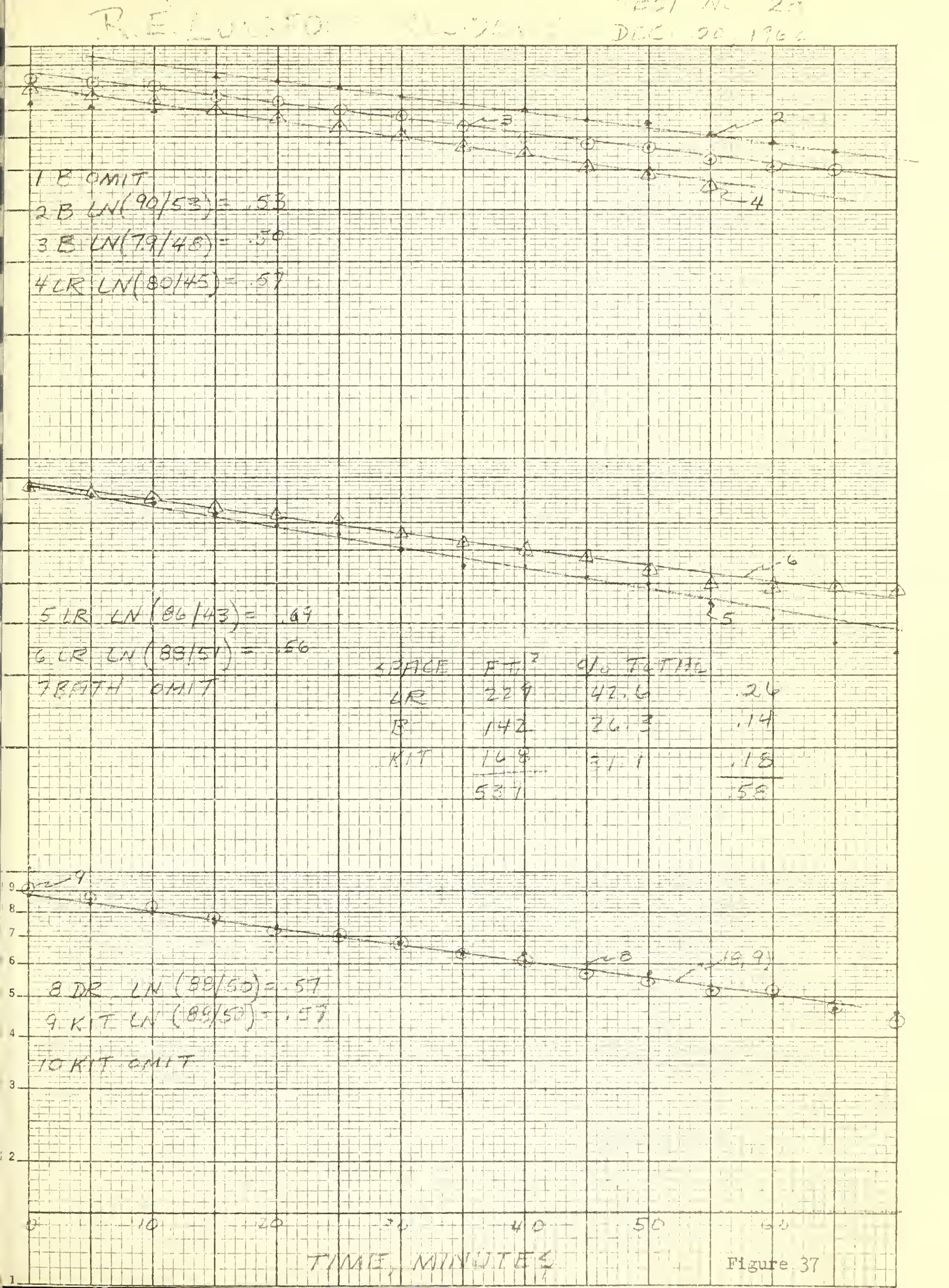

DEC. 20, 196
1 B OMIT
2 B LN(90/53) = .53
3 B LN(79/48) = .50
4 LR LN(80/45) = .57
5 LR LN(86/43) = .69
6 LR LN(88/51) = .56
7 BATH OMIT
SPACE FT² % TOTAL
LR 229 42.6 .24
B 142 26.3 .14
KIT 168 31.1 .18
537 .56
8 DR LN(88/50) = .57
9 KIT LN(89/50) = .57
10 KIT OMIT
(8, 9)
0 10 20 30 40 50 60
9 8 7 6 5 4 3 2 1
TIME, MINUTES

Figure 37

TEST No. 30
DEC. 21, 1960

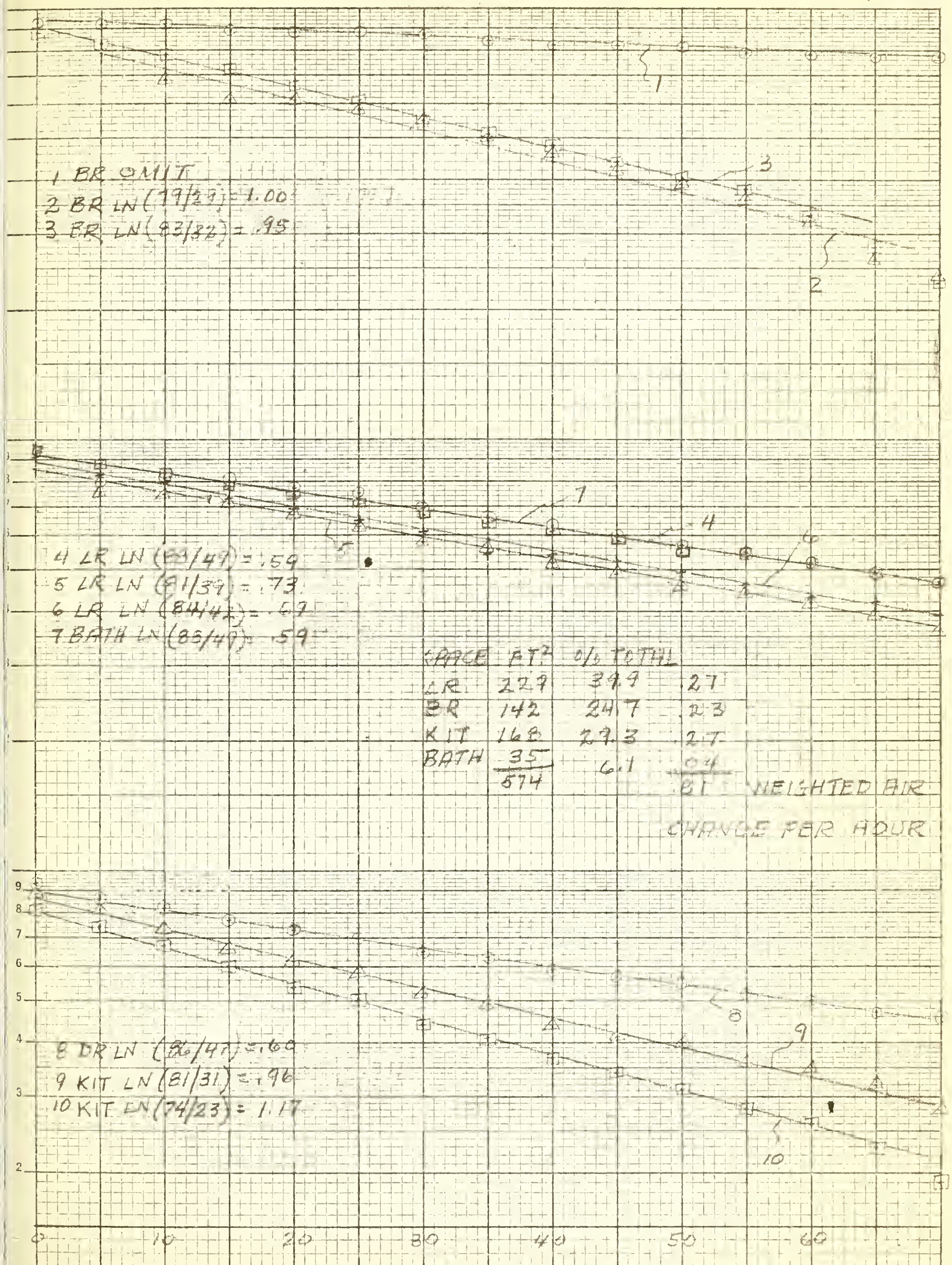


Figure 38

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Analytical Chemistry. Inorganic Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics'

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Crystal Growth. Physical Properties. Constitution and Microstructure.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

Atomic Physics. Spectroscopy. Radiometry. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry. Molecular Structure and Radiation Chemistry.

• Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Interval Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

Radio Systems. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

NBS