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INVESTIGATION OF SURFACE CONDENSATION IN A CMHC HOUSE IN HULL

by

A. G. Wilson

(Prepared for Central Mortgage and Housing Corporation)

Ottawa
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DBR Report
R 26

FOREWORD

This report is the written record of a study which was made late in the winter of 1949-50 at the request of Central Mortgage and Housing Corporation. The results of the study were communicated orally to the Corporation as soon as they were available. It has been felt desirable to prepare this written record in view of the interesting information which was obtained and of the increasing importance of the problem of condensation in the newer houses of Canada.

Attention may be drawn to the very high relative humidities which were found in the house which was examined. These demonstrate clearly the profound influence upon house performance of the type and number of the tenants concerned. If this report does nothing else, it shows vividly the impossibility of obtaining accurate results from any survey of occupied houses unless full consideration is given to the influence of those living in the houses which are studied.

The report is a small example of a record of the type of operational research which the Division of Building Research has long looked forward to carrying out in conjunction with Central Mortgage and Housing Corporation. It represents a further step towards a full and complete study of the problem of condensation. The report was prepared by Mr. A. Grant Wilson who carried out the field observations with the assistance of Mr. D. H. Marsland (C.M.H.C.) and Messrs. Gibbons and Ritchie of this Division.

Robert F. Legget,
Director,
Division of Building Research.

INVESTIGATION OF SURFACE CONDENSATION IN A CMHC HOUSE IN HULL

by

A. G. Wilson

This investigation of surface condensation was prompted by complaints received at the local CMHC office in Hull from the tenants of a $1\frac{1}{2}$-storey, basementless, Type H-12 house. Although the case appeared to be an isolated one, it was considered advisable to make a study of the contributory factors, in view of the seriousness of condensation problems experienced in similar houses on the prairies (see DBR R-16). Furthermore, the surface condensation problem in the west had occurred in houses insulated with Type 1 Alfol while this complaint involved a house insulated with 2-inch rock wool batts. Failure of the bathroom floor and a section of drain pipe had occurred. Damp crawl space conditions were suspected as being at least partially responsible and a study seemed warranted.

After a preliminary examination by DBR and CMHC staff members, humidity and temperature recording instruments were placed in the living quarters and crawl space of the house. Similar instruments were placed at the same locations in an identical house which had experienced no surface condensation trouble. During supplementary examinations, a section of the outside wall, where the most severe inside surface condensation had occurred, was removed and inspected for condensation within the wall. The crawl space was examined and inside wall surface temperature measurements were taken where the surface condensation was severe.

Description of the House

The house investigated is a $1\frac{1}{2}$-storey, Type H-12 basementless structure, located at 123 Montclair Blvd., Hull. It has 6 rooms consisting of living room, kitchen and 4 bedrooms. The wall construction consists of asbestos-cement shingles, building paper, wood sheathing, 2- by 4-inch studding, 2-inch rock wool batts with vapour barrier backing, and 3/8-inch plaster board. Heat is supplied by an oil-burning space heater in the living room and a coal-burning range in the kitchen. The windows are double hung with storm sash and without weather stripping. The ceilings are insulated, but the attic is not vented.

Preliminary Examinations

The house was first examined on the afternoon of Feb. 3, 1950. On questioning the housewife, it was learned that the house was ordinarily occupied by a family of eleven, but an additional six people were being housed temporarily. There were eight children with ages ranging from 1 to 10 years.

The housewife reported that condensation had occurred on the outside walls to a distance of 4 feet from the floor. This condition was reported to be most severe on the east walls of the house where bedrooms were located. On examination of the east wall, the moulding was found to be wet. The wall near the floor line felt cold and damp, getting progressively drier further from the floor, and felt dry to the touch at distances over 4 feet.

All windows were provided with storm sash and appeared tightly fitted. The windows were filmed with moisture and frosted at the edges of the glass. No windows were open on the first or second floors and it appeared that the windows were rarely opened. Icicles hung from beneath the window sills on the east exposure (see Fig. 2). This condition was not evident in adjacent houses.

The occupants complained of water dripping from the ceiling of the east upstairs bedroom. This ceiling was found to be stained and damp in spots. Unfortunately, it was impossible to examine the attic space for other evidences of condensation.

The bathroom was examined and the pipes found to be rusting and filmed with moisture. One section of drain pipe had been replaced after 4 months of service. The bathroom floor had been completely replaced after 3 years of service, the original floor having failed, presumably as a result of excessive moisture caused by condensation and the usual water spillage. The crawl space was inspected from the access door in the bathroom and the ground appeared damp in spots. The floor was uninsulated and the crawl space vents were tightly closed.

The atmosphere in the house seemed very humid. There was water in the space heater pan and a large pot of liquid was boiling on the kitchen range. The back door in the kitchen close to the range was covered with a heavy film of moisture.

On Feb. 7 the interior of the house was again examined. The outside walls of the living room were closely examined and considerable surface condensation was evident on the baseboard.

Portions of the wall behind furniture were filmed with moisture and it was noted that most of the living room outside wall had furniture placed adjacent to it.

Examination of Interior of East Wall

The east wall of the house was opened from the outside on the afternoon of Feb. 9. The wall was opened at a location where severe inside surface condensation had been reported. The asbestos-cement shingles were removed at the lower plate level, disclosing the building paper and sheathing. The sheathing and paper appeared dry, although there were a few very small spots of ice on the exterior of the sheathing. A piece of the sheathing was removed in order to inspect the rock wool batts. The batts were loosely stapled and the paper backing merely butted to the lower plate. Both insulation and studding were dry. The rock wool was pulled back to disclose the outside of the plaster board. It too was dry, although there was a stain near the plate which might have been caused by previous condensation.

On questioning the occupants, it was learned that the interior surface of the wall board had received 4 coats of oil paint since erection of the house.

Examination of the Crawl Space

The crawl space was examined by a DBR staff member on the morning of Feb. 14. At the time of the examination the crawl space vents were open, having been opened the previous day by the CMHC administrator.

The depth of excavation beneath the floor varied from 1 to 3 feet, making it possible to inspect closely only the east wall. The floor framing in the vicinity of the east wall is indicated in Fig. 1. For a distance of about 3 feet south of the beam on the foundation wall, the wall was badly broken with no mortar between blocks. There was evidence of repair work in this section and the CMHC administrator reported the possibility of the wall being broken during sewer repair work. North of the beam the foundation was sound. All blocks on the east wall were damp and filmed with moisture in spots. The sill plate was damp and discoloured, and all joists and beams in contact with the wall were damp. Large patches of mould were seen on the beam and on the first two joists north of the beam (see Fig. 3). The 2 x 8 above the sill, south of the beam was damp and discoloured. All the joists north of the beam had water droplets on the lower edges near the foundation wall (see Fig. 4).

The south wall could not be examined closely, but droplets of water could be seen on some of the concrete blocks. The sill plate and 2 x 8 above were discoloured and appeared damp. White mould was noted on the sub-flooring in the vicinity of the south wall. The west and north foundation wall could not be examined closely but appeared damp.

The earth in the crawl space was damp but no free water was noted.

Observed Data

Hygrothermographs and hygrographs were used to obtain records of temperature and humidity for a one-week period in the house under test and in an identical house (control house) experiencing no condensation trouble. For the most part the hygrographs were left in the crawl spaces while the hygrothermographs were used to obtain temperature and humidity records at the 30-inch and 0-inch levels in the living rooms and south-east ground floor bedrooms. For one day the hygrothermographs were located in the crawl space and the hygrographs located at the 6-inch level in the living rooms. The results have been plotted in Fig. 5. Unfortunately, the hygrothermograph in the control house lost its calibration in transit to the site and its readings have been omitted. Comparative readings obtained with the hygrographs have been shown, those readings obtained in the control house having been designated as such.

On the morning of Feb. 14, wall surface temperature measurements were taken on the inside surface of the exterior wall in the south-east ground floor bedroom. These readings were obtained with an Alnor portable pyrometer having an accuracy, according to the manufacturers, of 3°F. These readings and the locations at which they were taken are shown in Fig. 6. At the time the readings were obtained, only a few spots of moisture were noted on the wall and baseboard. One of the inside windows was open and considerable frost had accumulated on the glass of the storm sash.

Discussion of Results

The psychrometric principles governing condensation are treated at length in many texts. It suffices here to say that the appearance of condensation on a wall surface can be attributed to one or both of two factors:

1) High moisture content of a space,

2) Low wall surface temperatures.

In the case under consideration, the formation of condensation probably can be attributed to both factors.

1) High Moisture Content

The high moisture content of the living space is indicated graphically in Fig. 5. It is noted that at the 30-inch level in the living room the relative humidity rose to a maximum of 57 per cent, with a corresponding temperature of 70°F. At the 6-inch level the relative humidity rose to 68 per cent with a corresponding temperature of 60°F. The conditions in the south-east ground floor bedroom were more extreme with relative humidities rising to 70 per cent with a corresponding temperature of 57°F. Several factors are responsible for this high moisture content.

(1) The house is small and tightly constructed and the walls have a high resistance to water vapour transfer.

(2) An abnormal number of people occupy the house, a high percentage of these being children with attendant sources of moisture from cooking, washing and bathing.

(3) There is no basement in which to dry clothes, consequently some of the drying may be done in the living space.

(4) The tenants appeared to make no attempt to reduce the moisture content of the house. In spite of the already high humidities, water was kept in the space heater water pan.

(5) Ventilation through windows was kept at a minimum, possibly because of the borderline comfort conditions produced by the space heater.

Comparative relative humidity readings in the test and control houses at the 6-inch level in the living room were obtained on Feb. 10 and Feb. 11 and are shown in Fig. 5. Temperature distribution in the two houses can be considered similar so that the relative humidity readings can be used directly to compare moisture contents. The relative humidity reading in the test house averaged approximately 65 per cent, whereas that in the control house averaged approximately 35 per cent. Since the houses were identical, the lower moisture content in the control house must be due entirely to different operating conditions. The main factor was probably the more normal number of occupants in the control house.

2) Low Wall Surface Temperatures

Condensation will occur on a surface when that surface falls to the dew point temperature of the adjacent air-vapour mixture. The inside wall surface temperature depends on the relative thermal resistances of the inside air film and the remainder of the wall, as well as on the inside and outside temperatures. Under the usually assumed conditions of uniform inside temperature, calculated values of the wall surface temperature will be considerably higher than the calculated values of window surface temperature (at least for the house under investigation) and condensation would be expected to occur on the windows only. There are several factors, however, which tend to lower wall surface temperature on the lower portion of outside walls below that expected from the usual calculations.

(1) Inside temperature conditions are not uniform. The quality of heat distribution in a house is dependent upon the type of heating system and the general house layout. With the space type heater as used in the house under investigation, circulation of the warm air to rooms other than that in which the heater is located is by overflow only, and depends on the temperature difference between rooms.

Furthermore, the character of overflow heat distribution is such that extreme temperature gradients are set up between floor and ceiling. Although no concurrent readings of temperatures at the 30-inch and 6-inch levels were obtained, it can be judged from readings on consecutive days that the differences in temperature between these levels was in the neighbourhood of 10°F. to 15°F. in both the living room and bedroom, with outside temperatures varying from 0°F. to 25°F.

(2) With manual control of the heater, fairly large fluctuations of inside temperature with time are likely to occur. These fluctuations are evident in Fig. 5.

(3) Furniture and other objects placed close to outside walls further affect the temperature distribution in that they restrict the flow of warm air behind them and add some

thermal resistance to the wall to which they are adjacent. The net effect of objects placed close to outside walls is a lowering of wall surface temperatures in their immediate vicinity. This was evidenced in the house under investigation, with severe condensation occurring on living room outside wall areas behind furniture.

(4) The crawl spaces of basementless houses such as that under investigation tend to be cold. With uninsulated floors there is a relatively high heat loss through the floor, including those regions around the baseboard and plates of exterior walls. This is an additional factor in decreasing the inside surface temperatures of the lower portions of outside walls. In the house under test, crawl space vents were kept closed so as to maintain as high a floor temperature as possible. On the afternoon of Feb. 13 the crawl space vents were opened by the CMHC administrator and were left open through Feb. 14. On Feb. 14 the tenants complained of cold floors and severe wall surface condensation.

The combined effect of the foregoing factors affecting wall surface temperatures was to cause the surface temperatures of the lower portions of the wall to fall, at times, below that of inside window surface temperatures, thus making the wall areas the condensing surfaces.

Crawl Space Conditions

The crawl space conditions of the house under study have been described in the section "Examination of the Crawl Space". The humidities encountered are shown in Fig. 5.

There was some question at the time of the examination as to whether moisture conditions in the crawl space were responsible to some degree for the high humidities and surface condensation in the living space. This does not appear to be the case.

Although insufficient data were obtained to prove definitely that vapour transfer was from the living space to the crawl space rather than from the crawl space to the living space, all evidence points in this direction. Using the data available for midnight, Feb. 10, from Fig. 5 and assuming a temperature for the 6-inch level in the living room of 58°F., which was the temperature 24 hours previously, the conditions are as follows:

Living Room		Crawl Space	
Dry bulb temp. 6-inch level	58°F.	Dry bulb temp.	42°F.
Rel. humidity, 6-inch level	65%	Rel. humidity	73%
Grains of moisture per pound of dry air	46	Gr. moisture per pound of dry air	29

For this case the direction of vapour transfer would definitely be from the living space to the crawl space. Using the data available for noon, Feb. 8, the conditions in the living space are:

Dry bulb temp., 30-inch level - 60°F.

Rel. humidity - 43 per cent

Grain moisture per pound of dry air - 41

At the same time, the rel. humidity in the crawl space was 89 per cent. In order for the crawl space to contain 41 grains of moisture per pound of dry air, the crawl space temperature would have to be at least 40°F. Comparing the crawl space and outside air temperatures for midnight, Feb. 10, viz. 42°F. and 22°F. respectively, one would expect the crawl space temperature to be considerably lower than 40°F. at noon Feb. 8 when the outside temperature was 2°F. Again the direction of vapour transfer appears to be from the living space to the crawl space.

Furthermore, the crawl space in the control house was reported to be quite dry by the CMHC administrator. Fig. 5 indicates that the relative humidity in the crawl space was considerably lower than that in the test house. There seems little reason to believe that there would be much difference in ground moisture conditions between the control house and the test house only 3 doors away.

It is felt, therefore, that the high humidity conditions in the living space of the house under test were largely responsible for the high moisture content of the crawl space. This high moisture content led to the formation of mould and condensation on cold joists and foundation walls.

Conclusions

The conditions under which this house was operated would probably be considered abnormal. These conditions are considered primarily responsible for the condensation trouble experienced. The experimental data were limited by the test conditions and the instruments available. Conclusions from this report, therefore, are restricted in scope. Each special study such as this, however, adds to the general understanding of condensation problems and on this basis alone, this type of investigation seems justified.

(1) Low surface temperatures on the lower portions of the outside walls, inherent in basementless-type houses with uninsulated floors and overflow-type space heaters, combined with abnormally high relative humidities, were responsible for the severe wall surface condensation noted. The critical factor in this case was probably the high moisture content of the space resulting from the abnormal number of occupants.

(2) The abnormally high moisture content of the living space appears to be for the most part responsible for the abnormally high moisture content of the crawl space with resulting condensation on joists and beams and formation of mould. This high crawl space moisture content may have been responsible to a degree for the failure of the bathroom floor.

Possible Remedial Measures

1) Every effort should be made to reduce sources of moisture in the house. To maintain a reasonable moisture content in this house with such a high occupancy will be difficult, if not impossible. Certain sources can be removed however, with little or no inconvenience. For example, no water should be placed in the humidifier on the space heater and the needless boiling of water on the kitchen stove can be eliminated.

2) Increasing the ventilation rate of the house would help to some extent in reducing the moisture content of the living space and should help in preventing inside surface condensation. More frequent opening of windows is probably the only practical way to increase the ventilation rate. Under certain conditions, however, this may cause more severe condensation trouble by lowering wall surface temperatures still further.

3) The addition of insulation to the lower portions of the wall would increase the inside surface temperatures and would help to alleviate the inside surface condensation. It would not, however, help the crawl space conditions.

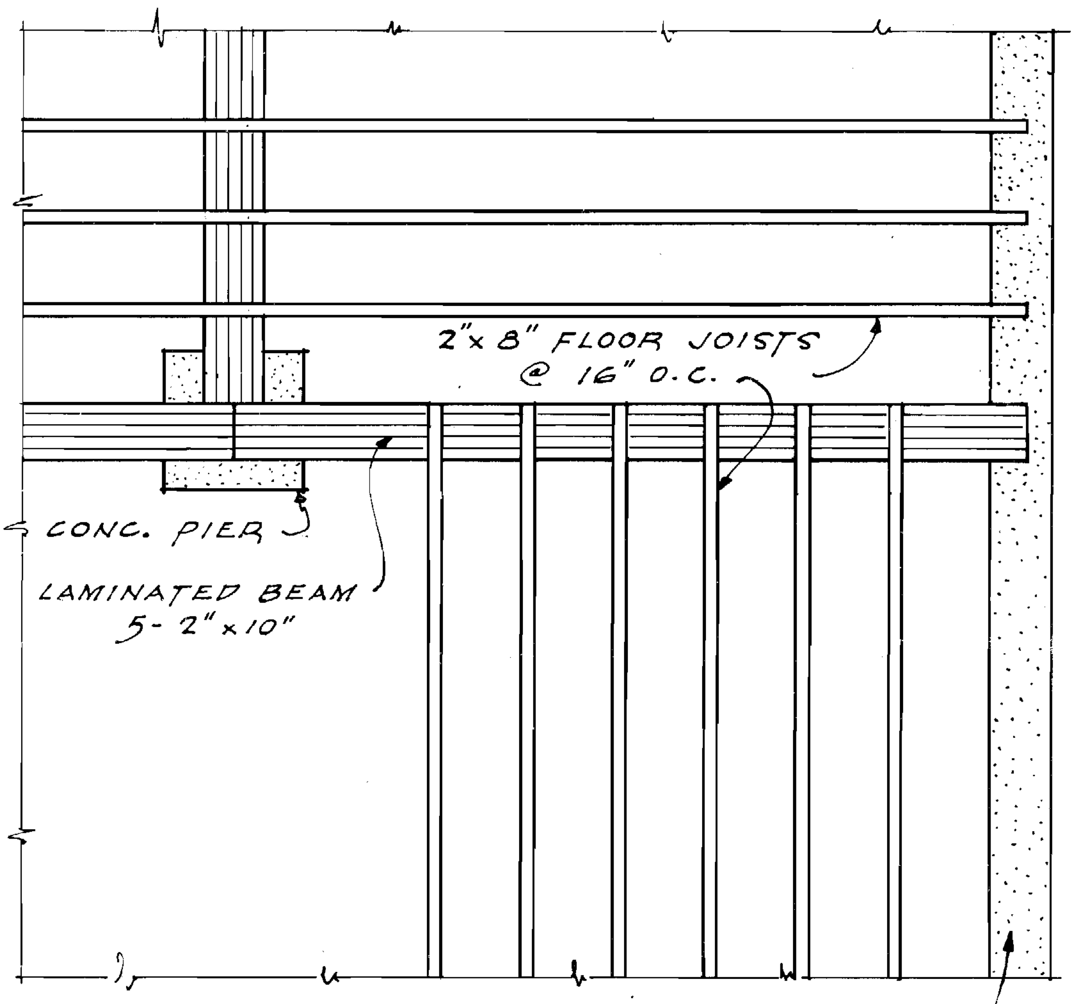
4) Ventilation of the crawl space would reduce the crawl space moisture content, but would result in cold floors and more severe wall surface condensation. A combination of floor insulation and crawl space ventilation, however, would reduce the moisture content of the crawl space to a safe level while possible increasing floor temperatures. Any increase in floor temperatures around outside walls would help to lessen inside surface condensation. With insulated floors, a proper vapour barrier should be provided. With or without insulated floors, a proper vapour barrier in the floor construction would help reduce moisture content of the crawl space.

5) As noted previously, there was evidence of attic condensation. The attic should be vented according to recommended practice.

FIGURE 1

TO ACCOMPANY

REPORT R 26 DATED OCT. 1950



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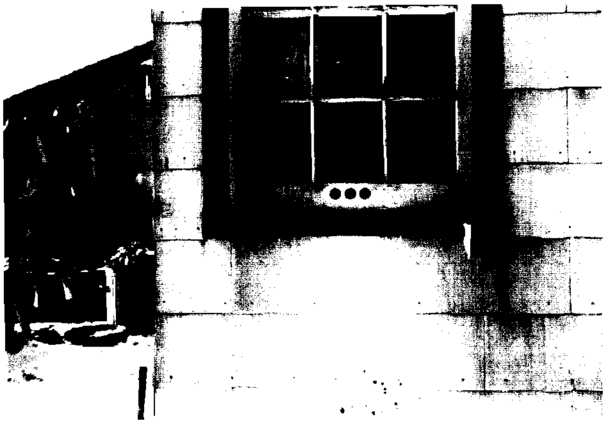

Fig. 2
Icicle on S. E. bedroom window

Fig. 3
Patches of mould on joists and beam

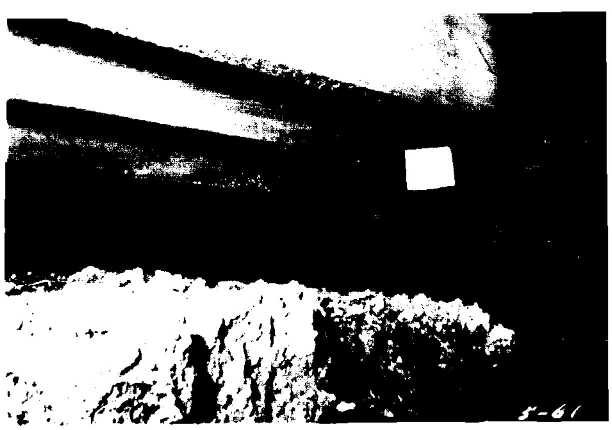

Fig. 4
Droplets of water on joists

FIGURE 5

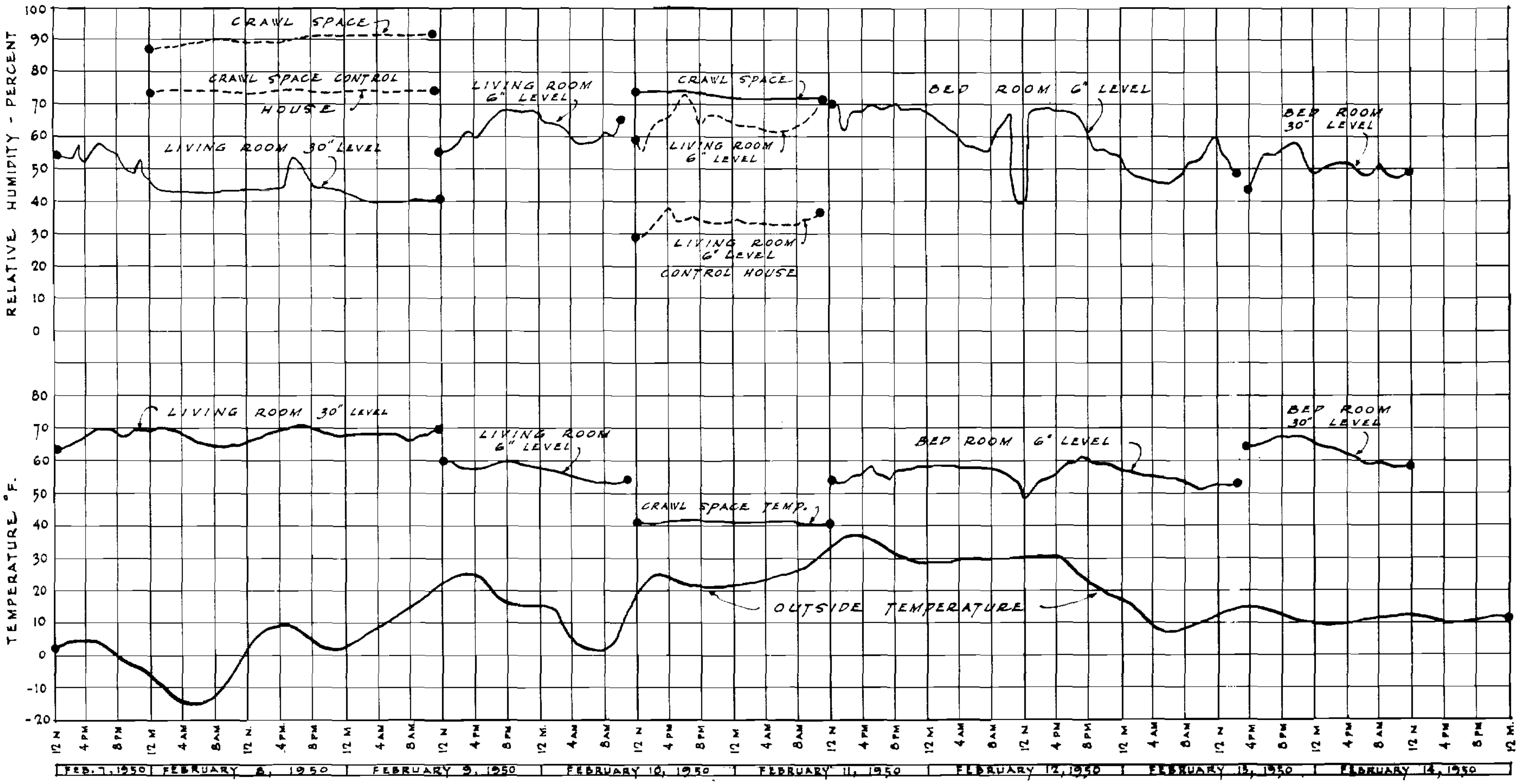
RELATIVE HUMIDITY - PERCENT
100
90
80
70
60
50
40
30
20
10
0
CRAWL SPACE
CRAWL SPACE CONTROL
HOUSE
LIVING ROOM 30" LEVEL
LIVING ROOM 6" LEVEL
CRAWL SPACE
LIVING ROOM 6" LEVEL
LIVING ROOM 6" LEVEL CONTROL HOUSE
BED ROOM 6" LEVEL
BED ROOM 30" LEVEL
TEMPERATURE °F.
80
70
60
50
40
30
20
10
0
-10
-20
LIVING ROOM 30" LEVEL
LIVING ROOM 6" LEVEL
CRAWL SPACE TEMP.
BED ROOM 6" LEVEL
BED ROOM 30" LEVEL
OUTSIDE TEMPERATURE
12 N
4 PM
8 PM
12 M
4 AM
8 AM
FEB. 7, 1950
FEBRUARY 8, 1950
FEBRUARY 9, 1950
FEBRUARY 10, 1950
FEBRUARY 11, 1950
FEBRUARY 12, 1950
FEBRUARY 13, 1950
FEBRUARY 14, 1950

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FIGURE 6

TO ACCOMPANY

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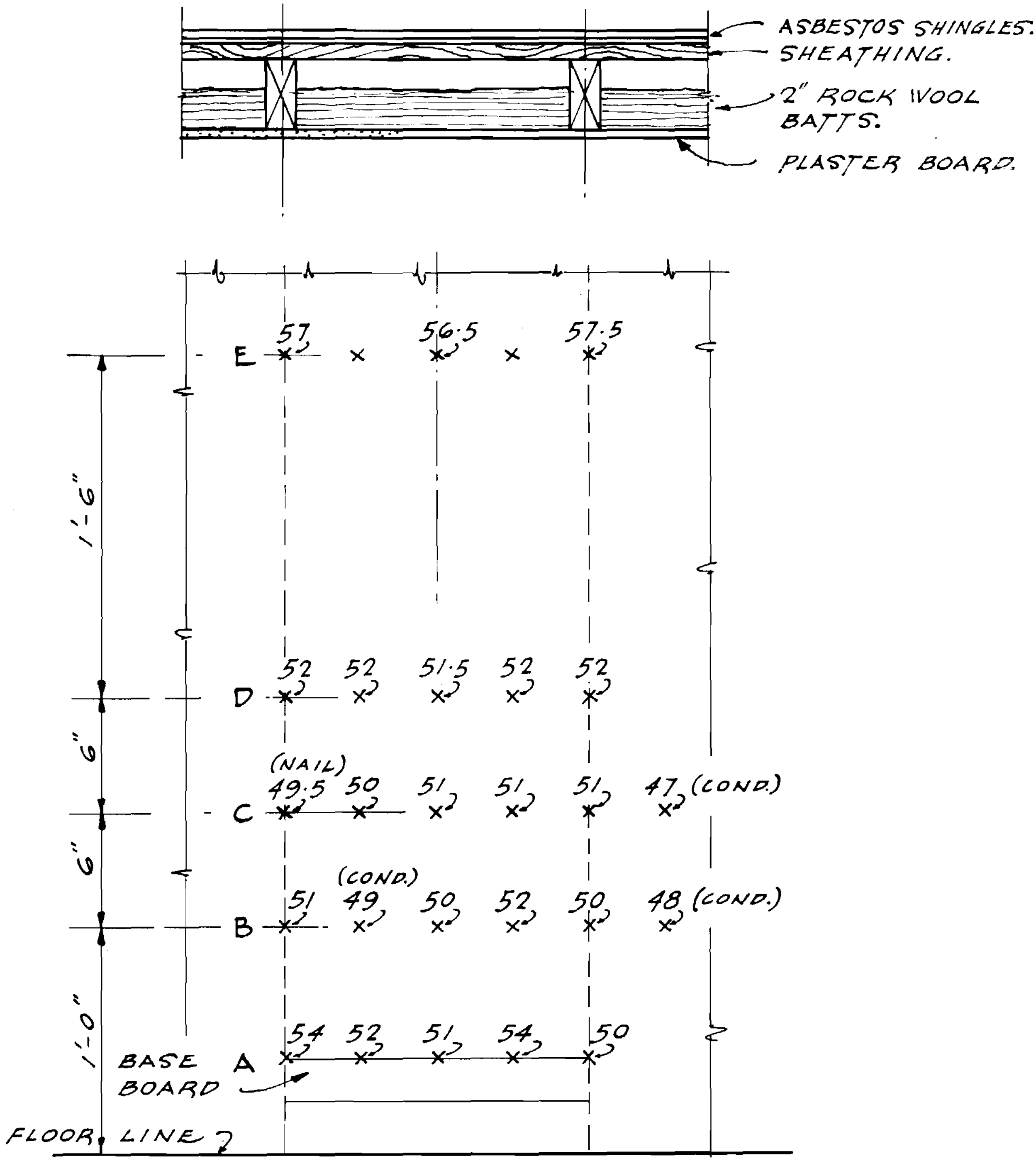

NOTE:

AIR TEMPERATURE @ 4' ABOVE FLOOR 58°F.
" " @ BASEBOARD 52°F.
WINDOW GLASS 45·5° - 46°F.
OUTSIDE TEMP. 12·5°F. FEB. 14TH. 1950 11·30 A.M.

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