Report of activities of DBR Building Services Section for the year 1960

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/20358695
Technical Note (National Research Council of Canada. Division of Building Research); no. TN-325, 1961-03-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

No. 325

TECHNICAL NOTE

NOT FOR PUBLICATION

FOR INTERNAL USE

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DATE March 1961

PREPARED FOR Informal Study Group on Heating and Ventilation

SUBJECT Report of Activities of DBR Building Services Section for the year 1960

This report of the work of the Building Services Section was prepared in the first instance for inclusion in the 1960 annual report of the Division of Building Research. It is reproduced here for the information of the Informal Study Group on Heating and Ventilation which is meeting in Vienna, June 5 to 8, 1961, and with which the Division is pleased to be associated. This report covers essentially all of the research activity related to heating and ventilation in the Division of Building Research for 1960.

The DBR Building Services Section is concerned with problems related to the use of mechanical services or equipment required in buildings. This includes responsibility for studies involving the thermal and moisture performance of the building enclosure. Much of the research carried out at the DBR Prairie Regional Station in Saskatoon falls within this sphere and in this connection the work of the two groups is closely co-ordinated.

Work has continued along four major lines: thermal and moisture performance of materials and materials in combination forming the building enclosure, performance of building equipment, heat and mass interchange between the enclosure and the environment, and heat exchange between the ground and associated structures.

THERMAL PERFORMANCE OF BUILDING ELEMENTS

Thermal Conductivity

Development of guarded hot plate facilities for measuring the thermal conductivity of insulating and other building materials has continued. Three sizes of plates, 8-, 12- and 18-in., are in use; these are the only such equipment generally available to the building industry in Canada at the present time. Comparison tests on reference specimens with the U.S. National Bureau of Standards, to ensure that similar standards are in use in both countries, have been completed. Close agreement was obtained. Investigation of the various sources of error in using the apparatus have continued. Attention is now being given to the problem of measuring appropriate average surface temperatures during tests on rigid materials that have some surface irregularity. The section is actively participating in the revision of the ASTM standard method covering the guarded hot plate.

There is an increasing number of insulation applications in which vapour flow on the low temperature side of the insulation is prevented or severely restricted, as for example in insulated built-up roofs, metal clad buildings, and insulated low temperature piping. In some of these systems it is difficult or impractical to ensure an adequate vapour seal on the warm side. The rate at which different insulating materials take on and release moisture under various ambient conditions and the effect of this moisture on heat flow is of great interest in these applications. Apparatus used to obtain such information has already been described (NRC 5743). In these measurements one surface of the insulation is exposed to a low temperature metal plate while the other surface is exposed to controlled air conditions. Information is being obtained on moisture gain and heat flow both with temperatures in the material and on the exposed surface below the ambient dew point, with and without freezing in the material. Included in the study are lightweight concrete, sprayed asbestos fibre, foamed polystyrene, corkboard and fibreboard. All permeable materials gain moisture rapidly under conditions of surface condensation. Rates of moisture gain with a condensing plane within the material are relatively slow and there is an indication that some materials come to equilibrium with the environment at relatively low moisture contents so long as freezing does not occur. On the other hand rates of moisture loss under isothermal room conditions may be relatively high.

A periodic heat flow apparatus intended to measure thermal conductivity and diffusivity of moist materials has been described (NRC 5743 p. 19). The development work during 1960 has been on

refinements in the data processing procedures and in carrying out an experimental program to evaluate the reproducibility and accuracy of the system. Reports are being prepared on data processing procedures and on results of the evaluation tests. This work has been somewhat delayed since the research officer in charge of the experiments has gone on educational leave for a year.

Water Vapour Transfer

Measurement under standard conditions of water vapour permeability of a wide range of membranes and other materials was continued as a service to the building industry. The section has participated actively in ASTM work on the improvement of test procedures. Studies made to reconcile differences in results of measurements between laboratories demonstrated that the permeance of cellulose acetate depended significantly on the relative humidity in which the specimens were conditioned prior to test. It is very likely that this hysteresis effect is present in other moisture sensitive materials. An investigation was carried out of the suitability of small bore tubes as a reference permeability specimen with which to check the vapour pressure in test cabinets. No reliable method was found to overcome the effects of air circulation in the cabinet on vapour flow in the tubes.

The construction of the large-scale heat flow apparatus (NRC 5421) for building sections up to 8 ft square has allowed simulation of the water vapour flow across openings in vertical walls, such as would occur with open windows or doors or, for example, in a conveyor belt opening between a warehouse and a cold storage room. The flow of moisture is a direct result of natural convection caused by differences in the density of the air on the two sides of the wall. Tests were made with rectangular openings up to 1 ft square in walls from 1 in. to $4\frac{1}{2}$ in. thick, but results are, in most instances, applicable for larger openings and thicker walls as well. Some additional tests were carried out with forced air flow parallel to the wall. Under certain conditions this situation resulted in a reduced moisture flow. The investigation of moisture transmission will be continued to determine the moisture flow for: (1) very small differences in air density on the two sides of the wall, (2) openings in horizontal floors or ceilings, and (3) forced air flow over the opening in a sealed room.

Humidity Measurement

Studies in the field of humidity measurement were continued at the DBR Prairie Regional Station using the controlled atmosphere producer. This apparatus is capable of producing an atmosphere of known relative humidity within 0.2 per cent relative humidity over a wide range of temperatures*. The system utilizes a recirculated air stream saturated at one temperature level and reheated to another to provide the required psychrometric conditions. It has been used in studies of the characteristics of lithium chloride humidity sensing elements. Information is now being obtained on the vapour pressures over saturated salt solutions under both static and dynamic conditions.

Walls and Windows

An experimental study has been made of performance characteristics of the guarded hot box or heat metering box used in conjunction with the large cold room for measurements of over-all heat transmission coefficients of building sections. This box and the large-scale heat flow apparatus (NRC 5421) are unique in that an aluminum radiant heating and cooling panel is used as the inner surface and also as an enclosure to guard against heat leakage. This permits control over both radiation and convection conditions to which test specimens are exposed and eliminates the traditional guard box, making it practical to measure heat flows through full-scale building sections. As a result forced circulation within the metering box is not required and inside surface heat exchange coefficients for the test sections are equivalent to those in practice.

Studies of various aspects of heat and mass transfer in windows have continued as one of the major projects of the section. An investigation has been reported of factors involved in controlling condensation between the panes of non-sealed double-glazed windows (NRC 5420, CBD 5). Studies have continued in the cold room on the effectiveness of thermal breaks or barriers used in the construction of aluminum frames for double windows. Without such barriers the inside surface temperature of the frame is much lower than that of the glass under winter conditions (CBD 4). Substantial insulating breaks are required

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* Till, C.E. and G.O. Handegord. A proposed humidity standard. Presented at the semi-annual meeting, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Dallas, Feb. 1 to 4, 1960.

in the construction of the frames to increase inside surface temperatures, if one of the objectives in using double windows is to permit the maintenance of building humidities to the point where condensation occurs on inside glass surfaces. The inside surface temperatures of glass and frame depend on the method of heating and details of construction surrounding the window. Information required on these and other factors pertinent to window thermal performance testing is being developed on behalf of both the Canadian Government Specifications Board, which is preparing specifications for windows, and ASTM which is preparing standard methods of test for windows.

Similarly, information is being developed relative to the standardization of window air leakage test apparatus and a draft of a test procedure has been prepared for ASTM. Comparison tests with other Canadian laboratories making air leakage measurements have begun using calibrated orifices as test specimens. A comprehensive study is nearing completion on the air leakage characteristics of wood horizontal sliding sashless windows. Such windows have come into wide use for residential construction in recent years and there is little or no published information on their performance.

Development of methods of evaluating sealing methods used in the construction of factory-sealed double glazing units has continued. Samples of most of the units marketed in Canada are being subjected to accelerated aging in the laboratory weathering apparatus already described (NRC 5270). Seal leakage is being detected through measurement of the dew point in the space between the panes and ability to maintain deflection of the panes on exposure to lowered pressure in a vacuum chamber. Specimens of all units have also been mounted on vertical outdoor exposure racks facing south to detect any sensitivity to ultra-violet radiation and to correlate performance under the laboratory cycle with that outdoors.

Test Huts

Studies of summertime condensation in insulated masonry construction have continued in Ottawa. The two brick test huts were insulated with 2-in. nominal wool batts with a small air cavity between the insulation and brick. The cavity was vented to outside in one hut and was unvented in the other. A polyethylene vapour barrier was used on the inside and the inside finish has been removed regularly for observations of moisture accumulation between the vapour barrier and insulation. Significant moisture accumulation has been observed in the unvented wall following

rainy weather, while the inside of the vented wall has remained essentially dry. At the Prairie Regional Station the test hut studies on the performance of different types of insulation with no vapour barrier were continued. Test panels, consisting of insulation applied to sheet metal exterior cladding, were used in this study to simulate the conditions experienced in metal buildings under prairie weather conditions with two different interior environments. Both roof and ceiling applications were involved, and measurements were made of total moisture accumulation and of moisture gradient through the material.

BUILDING EQUIPMENT

Chimneys

Studies of the safety aspects of various masonry chimney arrangements have continued. For this purpose test specimens 6 ft long are being observed when subjected to inlet flue gas temperatures of 500, 750 and 1000°F to steady state and to inlet temperatures of 1400 and 1800°F for consecutive 1/2-hour periods to represent chimney fire conditions. Records are taken of chimney temperatures, dimensional changes and cracking. To date several lined brick, concrete and pumice block constructions have been tested. Differences in the performance of the various arrangements have not been great. Exposure for 14 hours or more is required to approach thermal equilibrium conditions. At equilibrium with the 500°F inlet temperature the outside surface temperatures are approximately equivalent to the generally recognized maximum temperature limits for combustibles and in excess of these limits at higher inlet temperature. It would be unusual for masonry chimneys in service to be subjected to steady inlet flue gas temperatures for the time required for thermal equilibrium. A thermal analogue study has therefore been made of the effect of cycling flue gas inlet temperatures on chimney surface temperatures.

Initial studies of overfire and chimney draft during start-up with oil-fired furnaces having gun-type burners have been completed (NRC 6101). Measurements were made with a cool chimney following long burner-off periods and during normal cycling. Results have shown pressurization or loss of draft in the combustion chamber, and to a lesser extent at the barometric damper for brief periods. Results of previous studies correlating draft studies with models and with full-scale chimneys (NRC 5948) have shown that non-isothermal friction factors may differ significantly from the isothermal values normally used in the calculation of available chimney draft.

Heating Units

Co-operative laboratory studies at Queen's University on oil-fired heating units were completed. The studies in general had been planned to provide information that would lead to improvements in performance testing. This included effects on efficiency and output of rate of circulating air, firing cycle and burner type. Some studies were made of factors involved in evaluating conversion vaporizing burners. The final study was concerned with safety aspects of oil-fired space heaters as affected by firing rate, oil type and chimney draft, in relation to their use in Northern Canada.

Records of field performance of several residential oil-fired furnaces in Ottawa, and gas-fired furnaces in Saskatoon were completed. Similar studies have been started on oil-fired furnaces in residences in the Halifax area by the DBR Atlantic Regional Station.

THERMAL PERFORMANCE OF BUILDINGS

Heating and Ventilation of Basement Fallout Shelters

At the request of the Emergency Measures Organization, the Division has begun a study of the air temperatures and relative humidities and ventilation rates to be expected in a typical family basement shelter of the type recommended for protection against radioactive fallout. A shelter has been constructed and instrumented for this purpose in the basement of a house in Ottawa loaned to the Division by Central Mortgage and Housing Corporation.

Studies of air temperature and relative humidity in the shelter, the basement, and the house will be conducted both winter and summer, with the house normally occupied and with simulated shelter occupancy under emergency conditions. Ventilation rates will be studied to determine the adequacy of the vent openings and the need for direct venting of the flue gases from fuel-fired cooking and heating equipment.

Concurrently with the initial shelter studies, performance tests will be conducted of kerosene-burning stoves, heaters and lamps currently available in Canada to determine their heat output, combustion efficiency and general suitability for use in this type of shelter.

House Performance

Studies of temperatures and humidities and heat requirements in a number of houses in Ottawa and in Saskatoon (by the Prairie Regional Station) were essentially completed. Similar measurements have been started in the Halifax area by the Atlantic Regional Station. Some records of house temperatures and humidities in residences at Inuvik, N.W.T., are being obtained in co-operation with the Department of Public Works. Studies of air leakage rates in houses at Ottawa and Saskatoon have begun.

Heating and Cooling Loads

Heat transfer situations that occur inside a building are quite complicated. Solar energy enters through the windows

and falls on the floor and other surfaces where it is partially absorbed and partially reflected. Energy is released by lights and equipment in the building, and heat is exchanged between the building and the outside environment by conduction through the building envelope. Heat is continuously exchanged between the building components by radiation and between the components and the air in the building by convection. Thus an accurate calculation of the instantaneous heating or cooling which is required to maintain a specified building air temperature requires the solution of many simultaneous algebraic and differential equations.

An analogue type of computer is the most suitable machine for performing these load calculations. The analogue is particularly desirable for the calculation of building air temperature and wall surface temperatures for the situation where the capacity of the air-conditioning plant is not sufficient to keep the air temperature constant. The effects of changes in building design on the air-conditioning load can be determined readily with an analogue machine.

During 1960 the section has continued to study the application of an analogue to air-conditioning calculations. A paper (NRC 6099) shows the desirability of simplifying the analogue circuit as much as possible. A program has been carried out to check the validity of the following commonly used simplifying assumptions:

1. That combined convection and radiation heat transfer coefficients can be used

2. That the surfaces of walls are isothermal.

The analogue computer has also been used to determine the effect on cooling load of inside and outside shading and absorption and reflection properties of glass.

Weather Records and Data Processing

Development has continued of an automatic digital recording system for climate measurements. All the basic components have now been built or purchased and preliminary testing completed. The preparation of computer programs to allow automatic processing of the climate records has been started. It is expected that this system will go into regular service in 1961.

In keeping with the trend to use computers for routine analysis of experimental results, several of the section's strip chart emf recorders have been modified to permit digital output

on punched paper tape. The tape output includes the control codes needed by the Bendix G-15 computer so processing can be done by machine without any transcribing. When tabulation of the readings is all that is required, this is done with an electric typewriter - tape reader combination. An automatic twelve-point differential pressure recorder for chimney draft and building pressure measurements has been set up with the facility for tape output when desired.

GROUND HEAT EXCHANGE

Heat Transfer under Buildings

Investigation has been completed of the heat loss into the ground under two similar basementless buildings of 400 square feet area at Ottawa. These buildings were heated electrically by cable buried in a concrete floor slab. Test results for several years operation have resulted in an approximate correlation of heat exchange with difference in temperature between inside and outside air. Results of tests on a 1/10 scale model of one of these floor slabs were in fair agreement with the field tests (NRC 4688). An investigation of frost heave under cold storage buildings has been reported (NRC 5743).

The variability of weather, soil conditions, and building types to be found in practice limit the applicability of specific field measurements. Consequently emphasis is now being placed on a mathematical approach. Mathematical methods are now available for estimating the effectiveness of peripheral insulation around basementless buildings, and for determining the effect of snow cover. The problem of penetration of the annual weather cycle under buildings has been formulated and is presently being evaluated with the help of an electronic computer. A simple graphical method has been developed for the determination of the steady temperatures under city streets and basementless buildings of any shape. This same method can be used to estimate the region of unfrozen ground under rivers flowing in regions of permafrost in the far north. Methods are also being developed to determine the heat exchange and temperature distribution in the ground adjacent to basements.

Heat Transfer from Completely Buried Structures

The heat transfer in the ground about a buried pipe grid serving a heat pump has been studied. A detailed mathematical analysis, based on simple heat conduction theory, was in good agreement with field tests. A scale model of a buried pair of insulated pipes, such as would be found in a district heating system, was tested to estimate the temperature conditions under

which a protective asphalt coating would be damaged (NRC 4688). An investigation of the heat transfer from a city subway to the ground in connection with the problem of ventilation is at present being carried out.