# SOME PHYSICAL PRINCIPLES AFFECTING HOUSING.

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By the commencement of the present century, a traditional type of domestic building-construction had been developed fairly generally throughout the Dominion. This construction had proved itself both economical and at the same time reasonably well suited to the climatic conditions of the country. Nearly 90% of the houses built between 1890 and 1910 conformed in the main to the following general specifications:—

Framework of timber, usually 4 in. x 2 in., lined externally with weatherboards, and internally with rough lining, scrim and wall-paper. Stud heights usually from 10 to 12 ft. Ceilings also of timber, either dressed below and painted, or left rough and covered with scrim and wallpaper. The timber was all thoroughly seasoned before use, and this, together with the good craftsmanship prevalent at that time, resulted in a tight wall-construction which left a comparatively dead-air space between outer and inner linings. The roof was generally of corrugated iron, fitting tightly, and leaving a dead-air space over the ceiling. To this was added wood sarking in a large proportion of houses. Windows were high and hung in sashes, with counterweights, so as to open by easily variable amounts at top and bottom. Most of the rooms were provided with an open fireplace and chimney.

As a result of all this, houses were warm, dry, and usually well ventilated, without excessive draught.

Within the last 20 years, radical departures from this traditional mode of domestic building-construction have developed. Weatherboards are to a very considerable extent superseded by veneers of brick or asbestos cement or concrete and the like; while interiors (both walls and ceilings) are being lined with such wall-board materials as fibrous plaster, pumice-cement board or wood-fibre board, or with lath and plaster. A wooden framework is still preserved in most types of construction; but the timber is green or partly dried and, either through indifferent workmanship or by intention, the wall cavities are usually very heavily ventilated. Roofing iron has been largely replaced by tiles, which are far from airtight and often not even reasonably watertight. Stud heights have been lowered to 9 or even 8 ft., and sash windows have given place to casements, with or without leadlights. With these, draughtless ventilation is more difficult, and, in fact, in a remarkably large proportion of homes, draughts are avoided by the simple but noxious habit of keeping all windows strictly closed in all but the calmest and warmest of weather. Chimneys have disappeared from all rooms except the living room—at least in smaller houses.

These modern houses are found in general to be much colder, much more damp and much less adequately ventilated than were those of the older type. The reasons for the deterioration is not far to seek, if we inquire into the physical features associated with the new materials and modes of construction.

In the first place, the thermal insulation provided by the traditional construction was reasonably good. Methods have been developed at the Dominion Physical Laboratory of measuring heat losses through a typical wall section of a house on the site. This is achieved by applying an open heated box to the interior of an external wall, and measuring the heat input to the box and the temperature drop across the wall section when steady conditions have been established.

The box itself is heavily insulated and pressed tightly against the wall interior by braces and jacks. A fan circulates the heated air within the enclosure. In order to ensure that all the heat passes out through the section perpendicularly to the surface, the whole room containing the box is heated to the same temperature as the box.

In this way, a typical traditional wall section was found to have a thermal transmittance value (U) or about 0.27, the units being B.Th.U. per sq. ft. per hour per °F. temperature difference across the section.

In the modern house, the wall linings are poor insulators, are usually comparatively thin, are backed by a draughty cavity instead of a sealed one, and often do not have the outer protection of as poor a thermal conductor as weatherboard timber. In consequence, U values have been found to be much higher. Here are some typical values:—

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| Weatherboards and lath and plaster .. | 0.37 |
| Brick veneer and pumice-cement board | 0.54 |
| Brick veneer and lath and plaster .. | 0.60 |

Modern standards abroad call for U values of not more than 0.20; and values even as low as 0.15 are strongly recommended in Great Britain. These low values mean much less heat loss in cold weather, and much less fuel consumption to keep the interior warmed up to comfort levels. It will be realised therefore that the high values discovered in modern New Zealand dwellings convey a very pointed condemnation of our present-day building methods.

Turning next to the problem of ventilation, we have found that the rate of ventilation in modern domestic rooms, in reasonably calm weather and with windows closed, is usually less than one air change per hour.

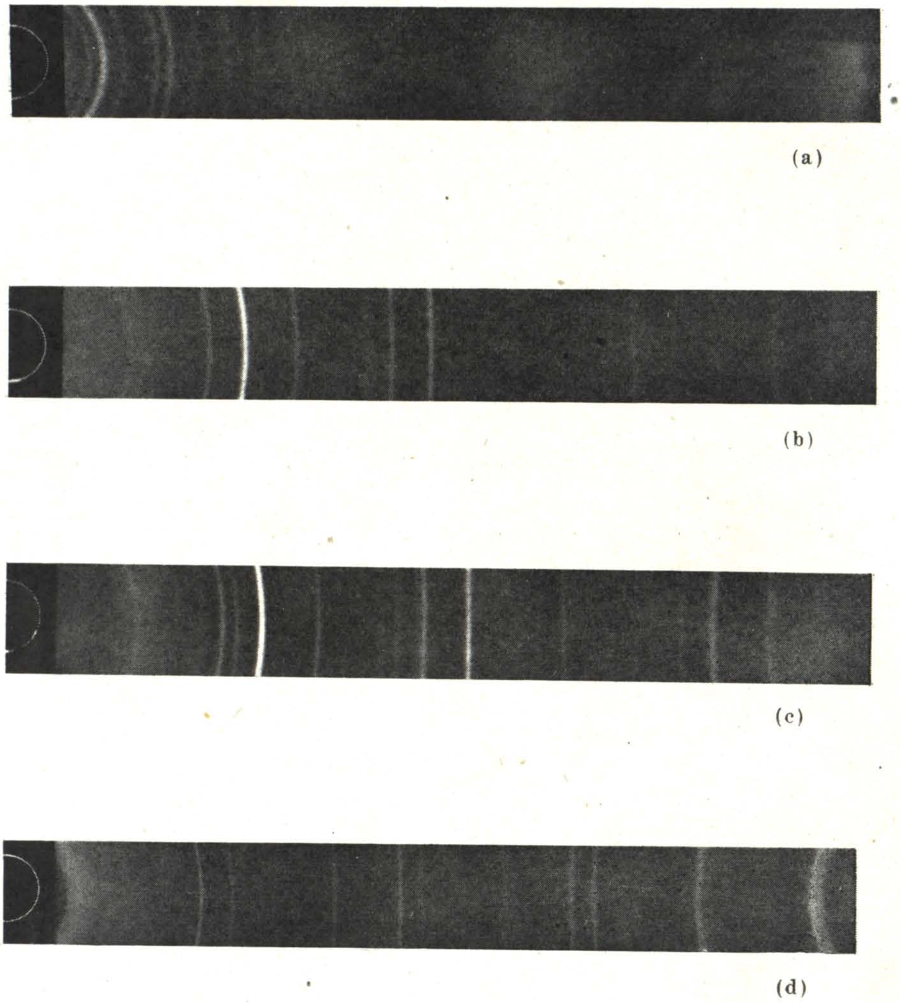
This has been measured by releasing about 1% of hydrogen gas into the air of the room, and measuring the rate of replacement of the mixed air by fresh outside air, by an electrical method. The method depends essentially on the high thermal conductivity of hydrogen compared to air. We have found it convenient to employ an aeroplane fuel-air-ratio analyser, which estimates the proportion of carbon dioxide in the exhaust gases of the engine. The method gives results which agree with more direct but less convenient methods to within 2 or 3%.

As a result of these measurements, we have learned that the effect of a sash window open slightly top and bottom is much more effective than that of a casement window open a similar amount; and that in a room with an open chimney, ventilation rates are from two to three changes per hour without a fire, and more than double that amount when a fire is burning.

The most serious consequence of this combination of low ventilation rate and high thermal loss is the development of very high humidities in occupied rooms. The moisture contributed to the air by the occupants builds up into high moisture contents which the ventilation is inadequate to remove, and which the low wall temperatures in the winter convert to high relative humidities. Rooms are damp, and unhealthy, and in over 50 per cent. of modern houses, mould develops on ceilings and walls. This mould rapidly disfigures very seriously interior finishings, and results in a demand for more frequent re-decoration.

The fundamental remedy for this dampness and mould in houses must clearly lie in an increase in ventilation together with a decrease in thermal losses through walls, ceilings and floors. So far has the theory of this problem now advanced, and been confirmed by experimental methods, that it has been found possible to survey a room and calculate the extra insulation and ventilation necessary to remedy the mould and dampness, under given external conditions. Unfortunately the remedy is expensive, both in houses during erection and especially in such as are already erected. It is probable, therefore, that those responsible for the present chaotic state of housing comfort will hesitate as long as possible to apply these remedies in order to put the matter right.

A further important problem of domestic comfort is at present under investigation. The open hearth fire as a means of household heating has always been in favour, in spite of its recognised inefficiency. So long as fuel is cheap and abundant, little attention is paid to the wastage. Now, investigation has been prompted by scarcity and costliness, and it has been shown that little more than about 15 per cent. of the heat available in even the best of domestic coal goes to increase the comfort of the household. More efficient methods of utilising the heat without losing the homeliness of the open fire are under consideration. By using the convective heat in a heat exchanger and by suitable control of the air supply to the fire, a considerable increase in efficiency has been secured in Britain. It is not certain if these improvements can be applied without modification to our locally available fuels, and until experimental work has been carried out on these lines, no very satisfactory conclusions can be drawn. At the moment, progress is held up for lack of a



Diffraction patterns of:

(a) Magnetite with Molybdenum Radiation.
(b) Magnetite with Cobalt Radiation.
(c) Magnetite with Unfiltered Iron Radiation.
(d) Silver with Copper Radiation.

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specially-designed laboratory. In this it is hoped to be able to measure the total heat contributed to the room, by making the room behave as its own calorimeter. When funds are available for this project, it is confidently expected that much saving in fuel and a much more efficient method of domestic heating will be developed, in spite of the low quality of the fuel at present available for household use.

But even if an efficient method of room heating is introduced, our room will not warm up quickly if the walls consist of material of low insulating quality or of high thermal capacity. There is on record an outstanding example of this. A room lined with plaster usually took about an hour and a-half to warm up to comfort levels in the winter mornings. When, however, the lining was supplemented with oak panelling, the same gas fire was able to warm the room adequately in half-an-hour. The panelling improved the insulation of the room, but more important, being constructed of a material of low thermal capacity, its temperature rose much more rapidly than did the plaster. In consequence, radiant heat was returned to the room more rapidly and the room reached a level of comfort much more quickly. The development of new types of wall-linings having these desirable characteristics is fraught with difficulty, because other factors must be kept to the fore. Of these, cheapness of manufacture and ease of application are of prime importance. There is a big field for a young physicist in this domain. But with the present shortage of qualified men interested in classical aspects of the science, progress must necessarily be slow and results delayed.

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# X-RAY DIFFRACTION OF IRONSAND.

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New Zealand's ironsands, particularly those on the west coast of the North Island, have long been regarded as a potentially rich source of iron. Now their relatively high titanium content has aroused considerable interest, and their smaller vanadium content is also considered worth attention.

The sands consist of grains of many different minerals. The proportions of these vary from place to place, even from one part of a beach to another; and the South Island ironsands differ very considerably from those of the North. In the North Island sands, the mineral present in quantity from which iron should most conveniently be extracted is magnetite ($Fe_3O_4$), and as this is strongly magnetic it can readily be separated almost completely from the other materials. The grains of magnetite are found to contain one-tenth as much titanium as iron, and a small quantity of vanadium.[1] This unusually large proportion of titanium is the main reason for the failure of past attempts to work the sands.[2] In a blast furnace titanium forms heavy infusible slags which accumulate at the bottom and soon put the furnace out of action. No method of reducing the titanium content before sending the magnetite to the furnace has yet been devised. Monro and Beavis[1] concluded from chemical evidence that the titanium atoms are actually in the magnetite lattice, i.e., some of the lattice points normally occupied by iron atoms are occupied by titanium atoms. This arrangement is known to occur in some minerals in other parts of the world. Chemical evidence alone, however, cannot settle this matter, and the only way of obtaining the necessary further information is to apply the methods of X-ray crystallography.

The apparatus used to do this is that designed by Williamson and constructed at the Dominion Physical Laboratory.[3] It consists of an X-ray tube with interchangeable anticathodes and the necessary pumps and power supplies, and a Debye-Hull powder camera. The method requires substantially monochromatic X-rays. These are obtained by strongly exciting the characteristic K radiation of a suitable metal used as the anticathode or target, and removing the unwanted $K\beta$ line with a suitable filter. The material to be studied is ground up to a fine powder, bound together with a gum containing only light atoms, and formed into a very thin rod which is slowly rotated at the centre of the camera (with its axis vertical) while a narrow (horizontal) beam of monochromatic X-rays