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Climate and Architect-Designed Houses

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A simple computer simulation program is used for the assessment of the thermal performance of several award-winning architect-designed houses in the Brisbane area. The results show that underheating is a greater problem than overheating and that a builder's house (with slight improvements) performs better. The conclusion is that excellent design features can be negated by simple faults, therefore all factors must be considered at the design stage in their interaction.

The Problem

It is almost axiomatic that a house should be designed and built to suit the climate of its location. A climatically well designed house would improve the thermal comfort of its occupants or reduce the energy used for active thermal controls. The great majority of houses built in Australia have no regard to the climate whatsoever. It is true that most of these houses have never seen an architect, but are architect-designed houses any better?

In order to avoid sweeping generalisations, it has been decided to re-phrase the question in more specific terms: Are the "best" architect-designed houses suitable for Brisbane's climate? Ideally, the answer to this question should be based on longterm (at least a year) monitoring of the thermal performance of these houses. This would require sophisticated and expensive equipment and would also interfere with the normal life of the occupants. Furthermore, as user behaviour can drastically change the thermal performance, the basis of comparison would be uncertain.

For these reasons it has been decided to use a readily available computer program and simulate the thermal response of a number of selected houses. By this method "all other things", i.e. occupancy, lighting and appliance loads, ventilation rates, etc. can be kept constant and the results would show the thermal behaviour of the building only.

The program

The computer program selected for use in this study is HARMON, developed at the Architectural Science Unit of the University of Queensland, which is based on the UK. BRE "admittance procedure" and is described by Szokolay and Ritson in this issue of ASR. This was readily available, at no cost and initial validation studies showed that it compares favourably with several recognised, more sophisticated (and more expensive) simulation programs.

As at the time of starting this study the program was only validated against a simple test-hut, it was thought to be necessary to verify it against measured data, using a full size house. An unoccupied house (the "Beaufort") by Jennings Homes was made available (Fig. 1). Its internal temperatures were measured for one week, together with simultaneous outdoor temperatures and solar irradiance. Fig. 2 shows the measured and predicted temperature profiles for a typical day. The general shape of the curves are similar, but not identical. However, the maximum and minimum values are almost the same***, therefore the program can be accepted as a valid tool for assessment.

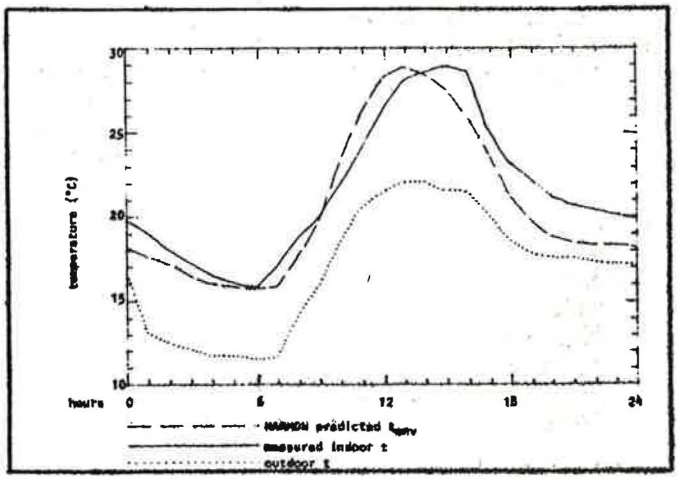


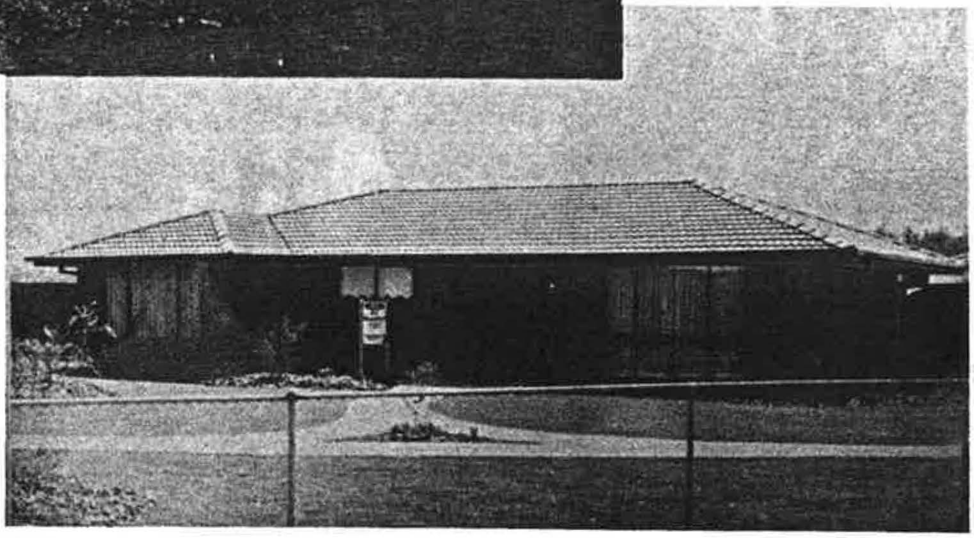
Fig. 2 Temperatures measured and predicted by HARMON for house No. 5.

The Sample

Records of the Queensland Chapter of the RAIA were searched and four award winning houses were selected. It is not the purpose of this study to criticise individual designs or designers, therefore the houses will only be identified by number and the architects or owners will not be named.

House 1 - bronze medal winner in 1978 - is shown in Fig. 3. It is a two-storey, three-bedroom house, with concrete slab-on-ground, cavity brick wall, timber upper floor, terracotta-tiled roof and plasterboard ceiling. Most windows face south-west and north-west. The maximum calculated ventilation rate is 46 air changes per hour (see explanation below, under "Method").

- * Recent graduate, this paper is based on his B.Arch.thesis.
- ** Reader and director of the Architectural Science Unit, University of Queensland.
- *** in a latter version of HARMON the admittance of internal partitions are taken into account, which brings the measured and predicted temperature profiles closer together.



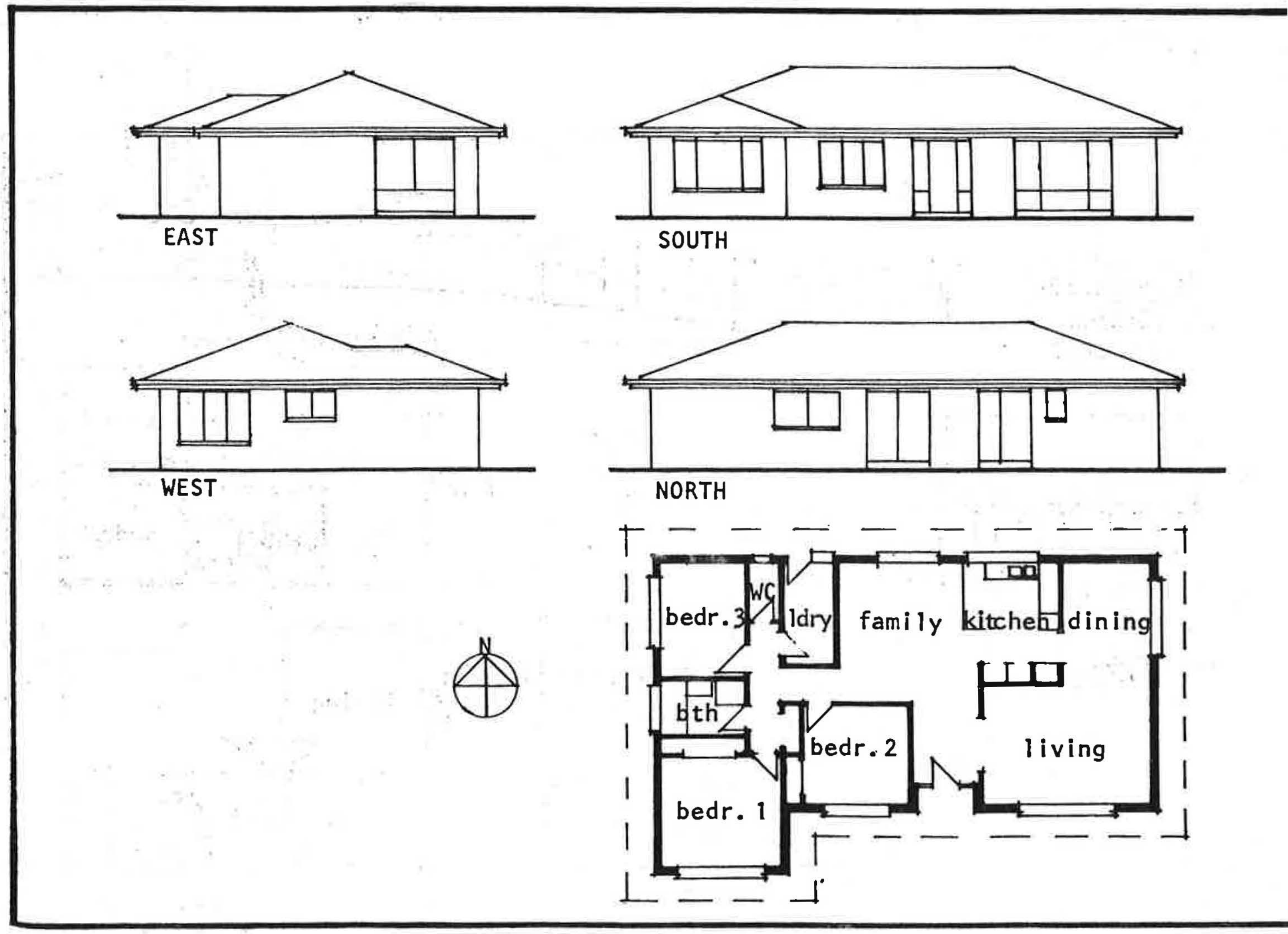
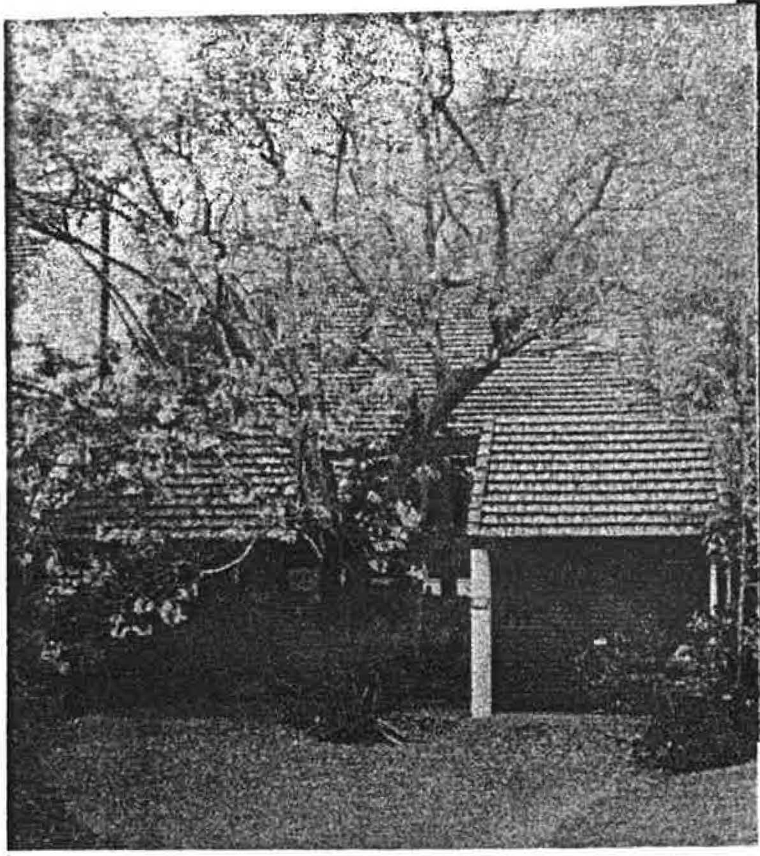
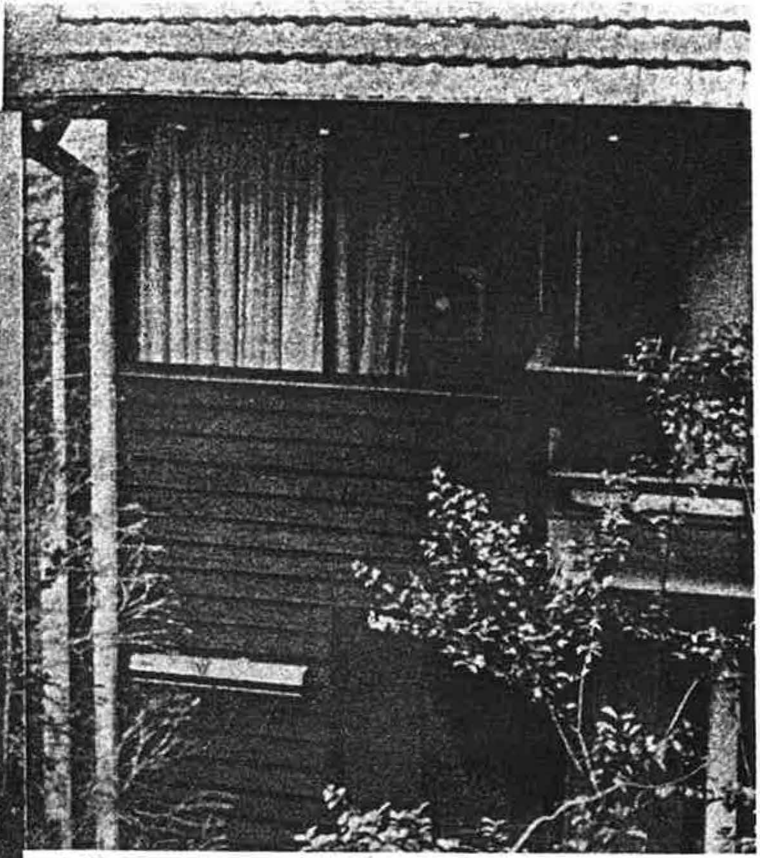


Fig. 1 House No. 5:"The Beaufort" by Jennings Homes.





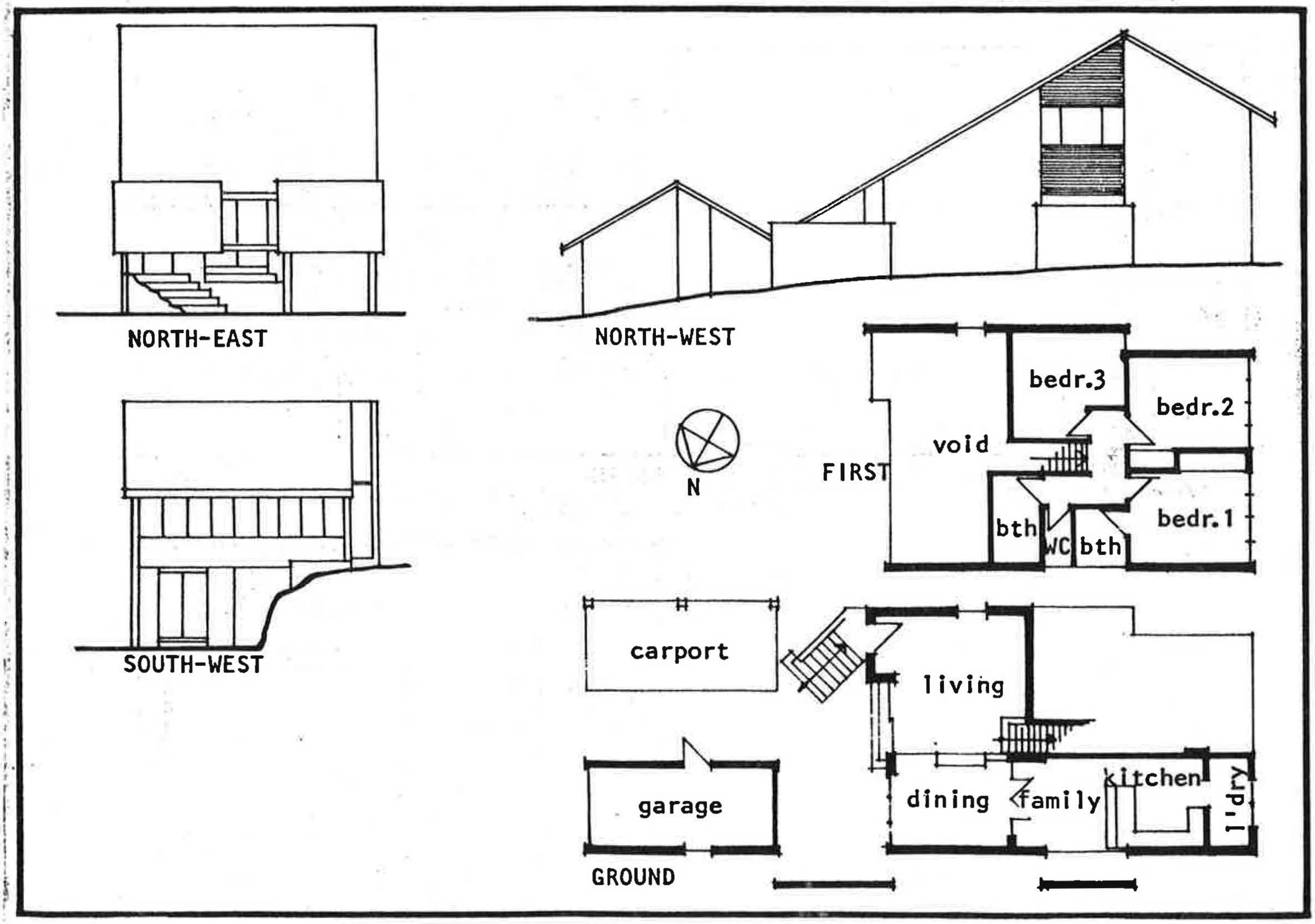
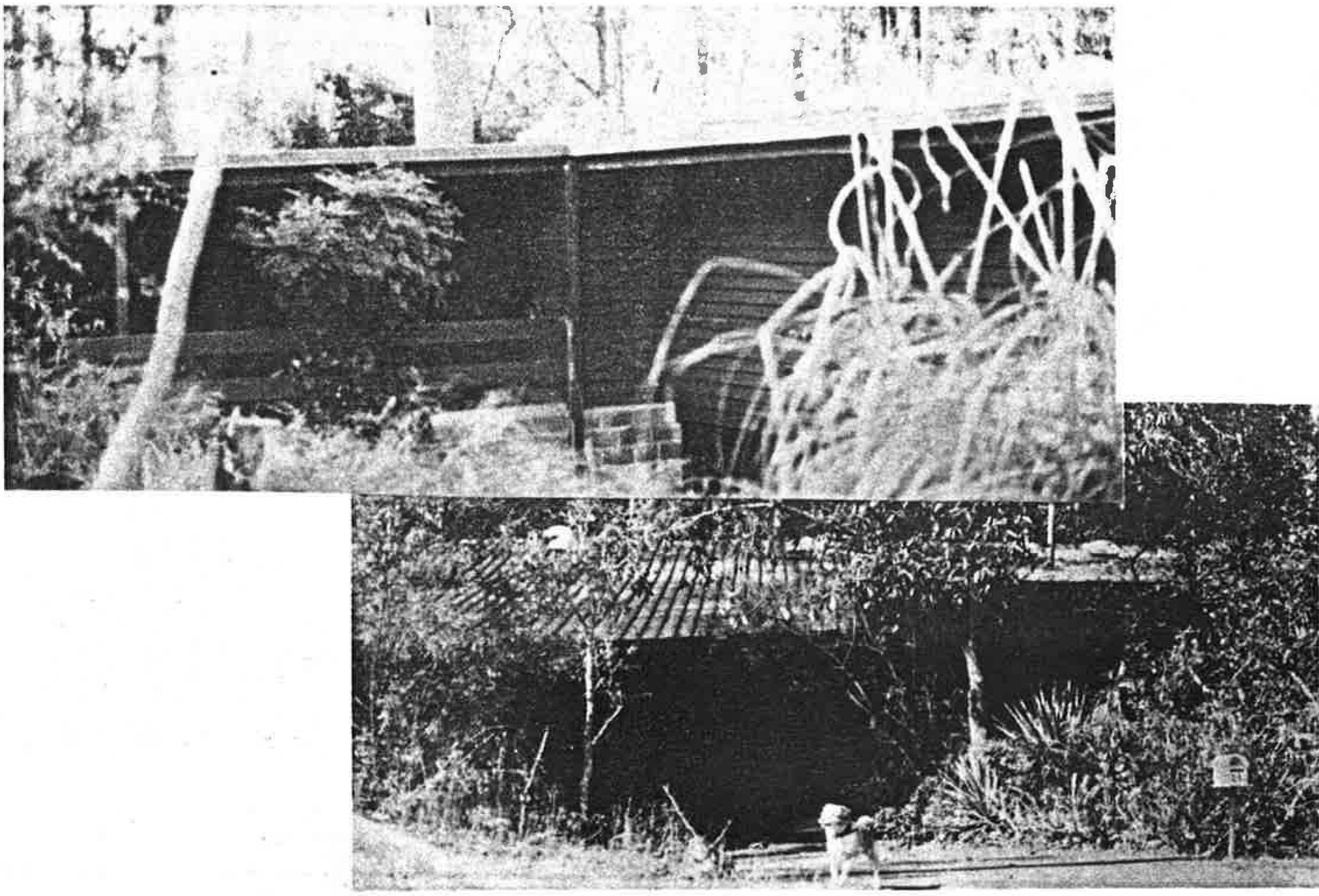


Fig. 3 House No. 1



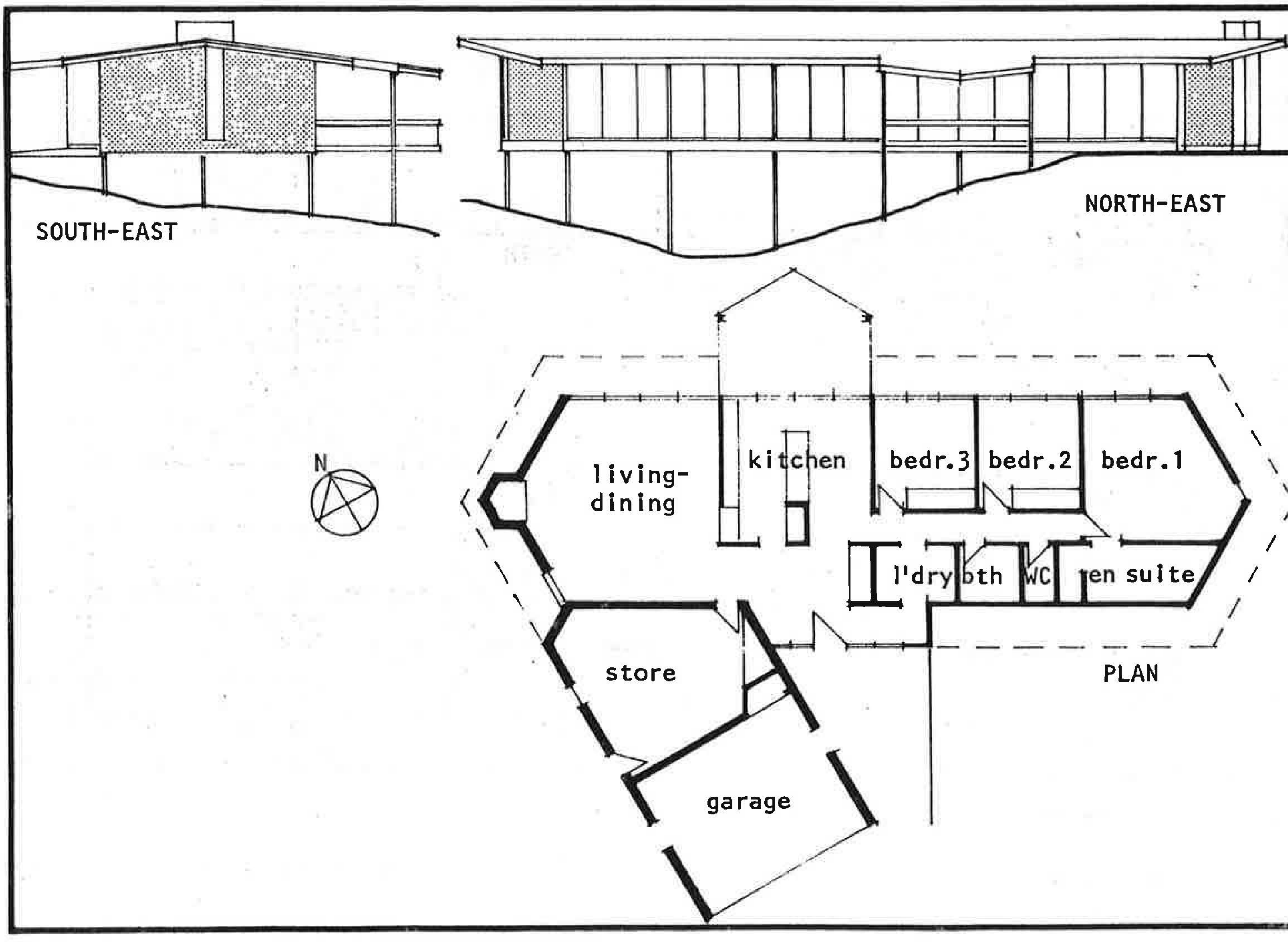
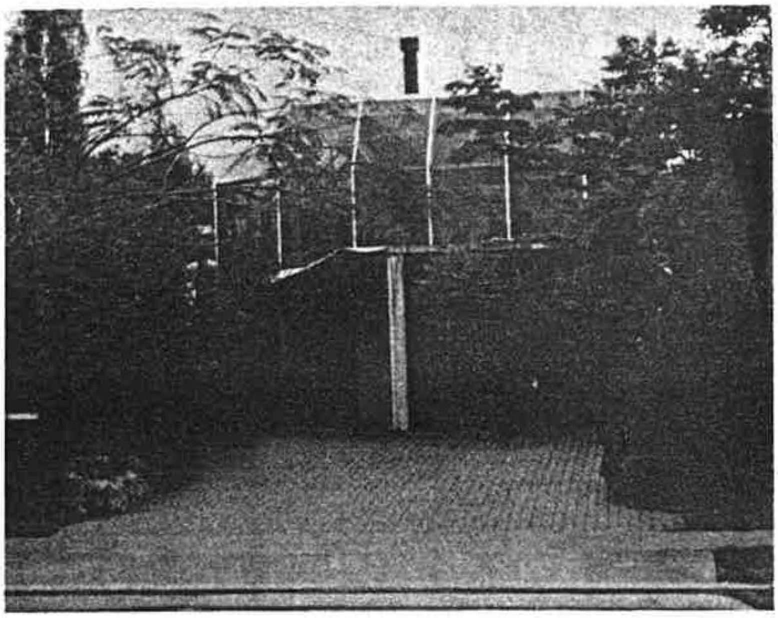
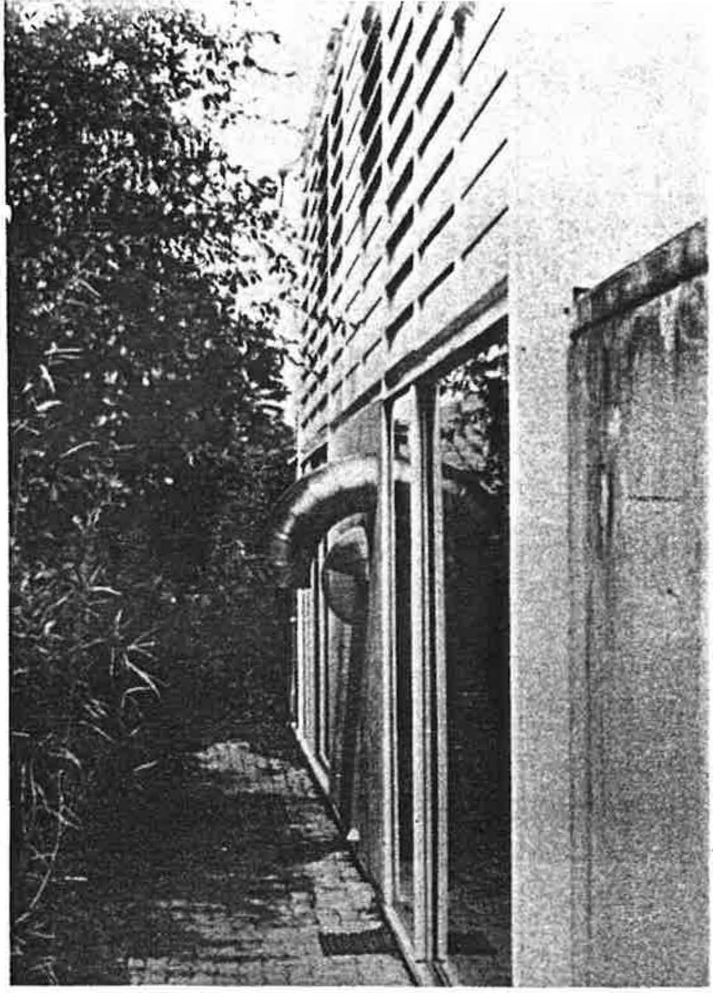


Fig. 4 House No. 2





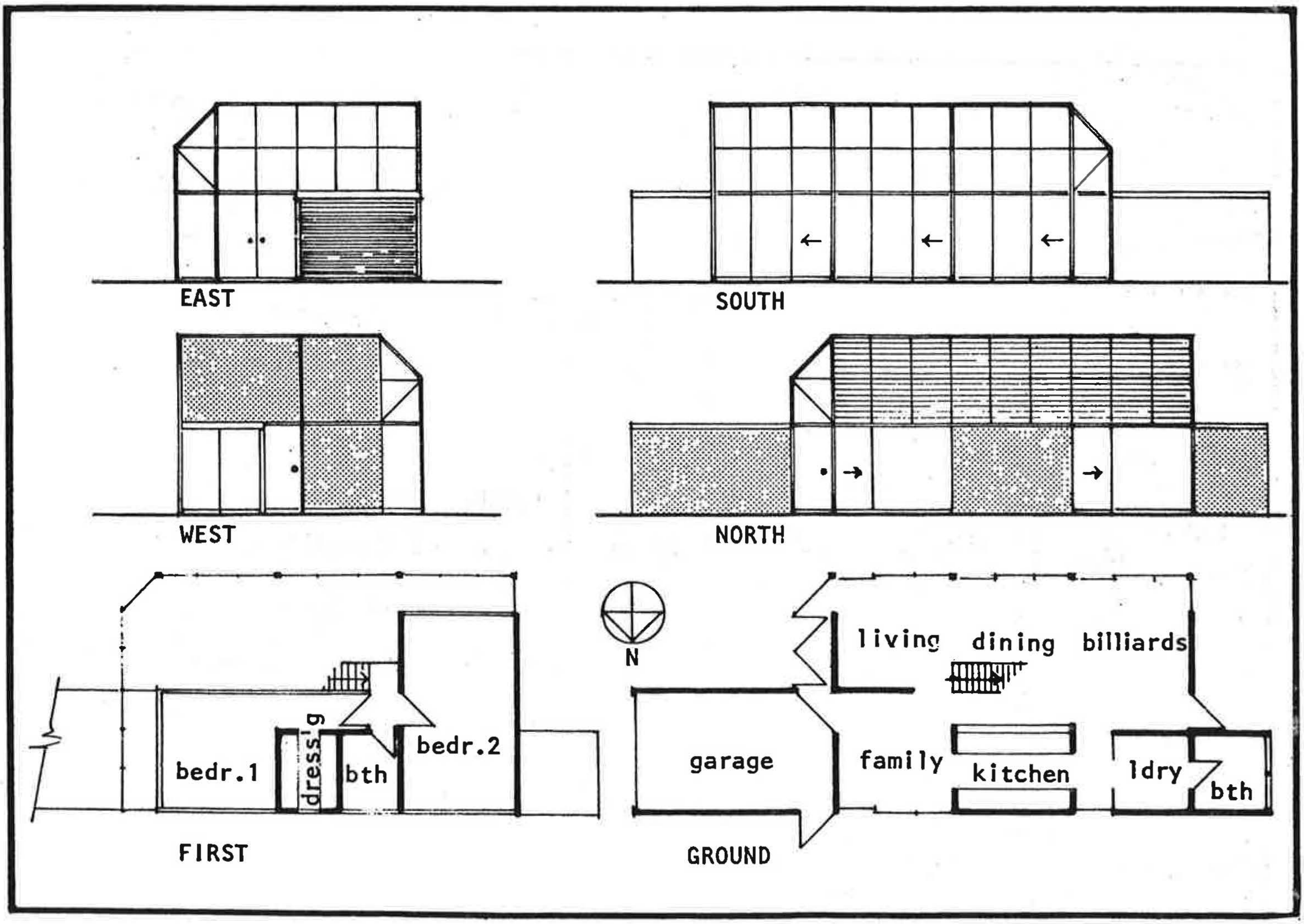
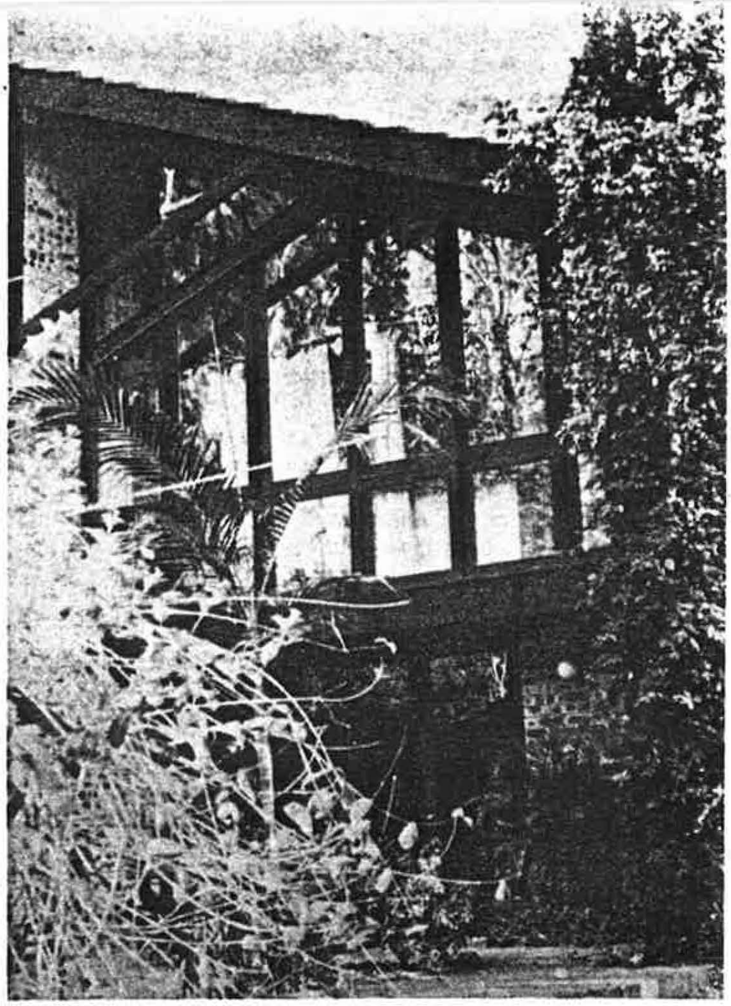
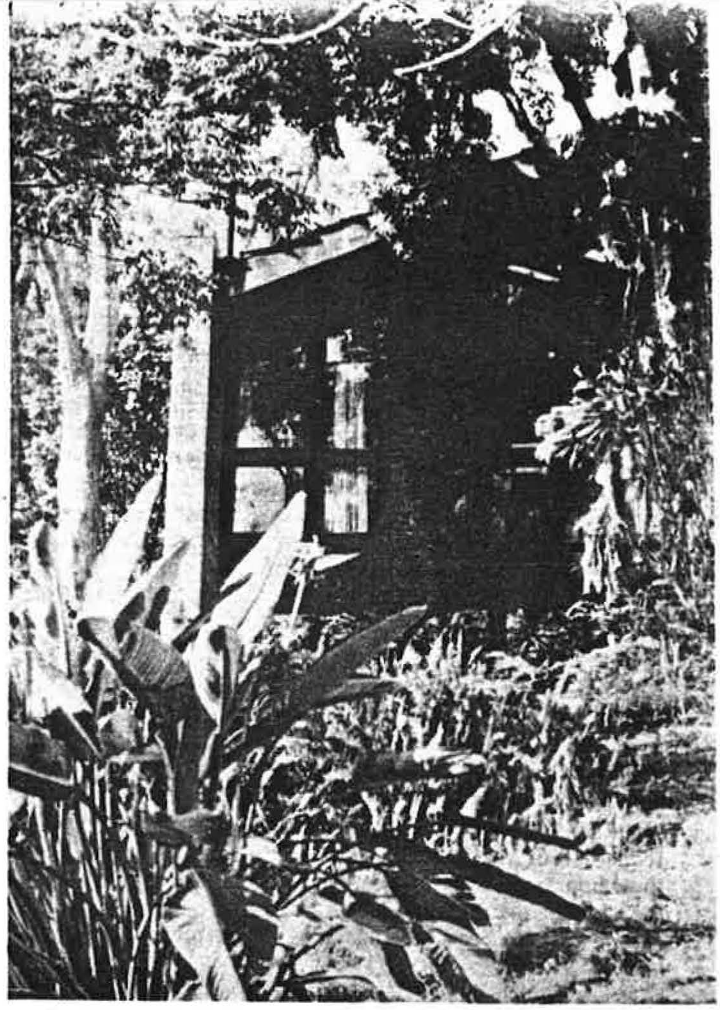


Fig. 5 House No. 3





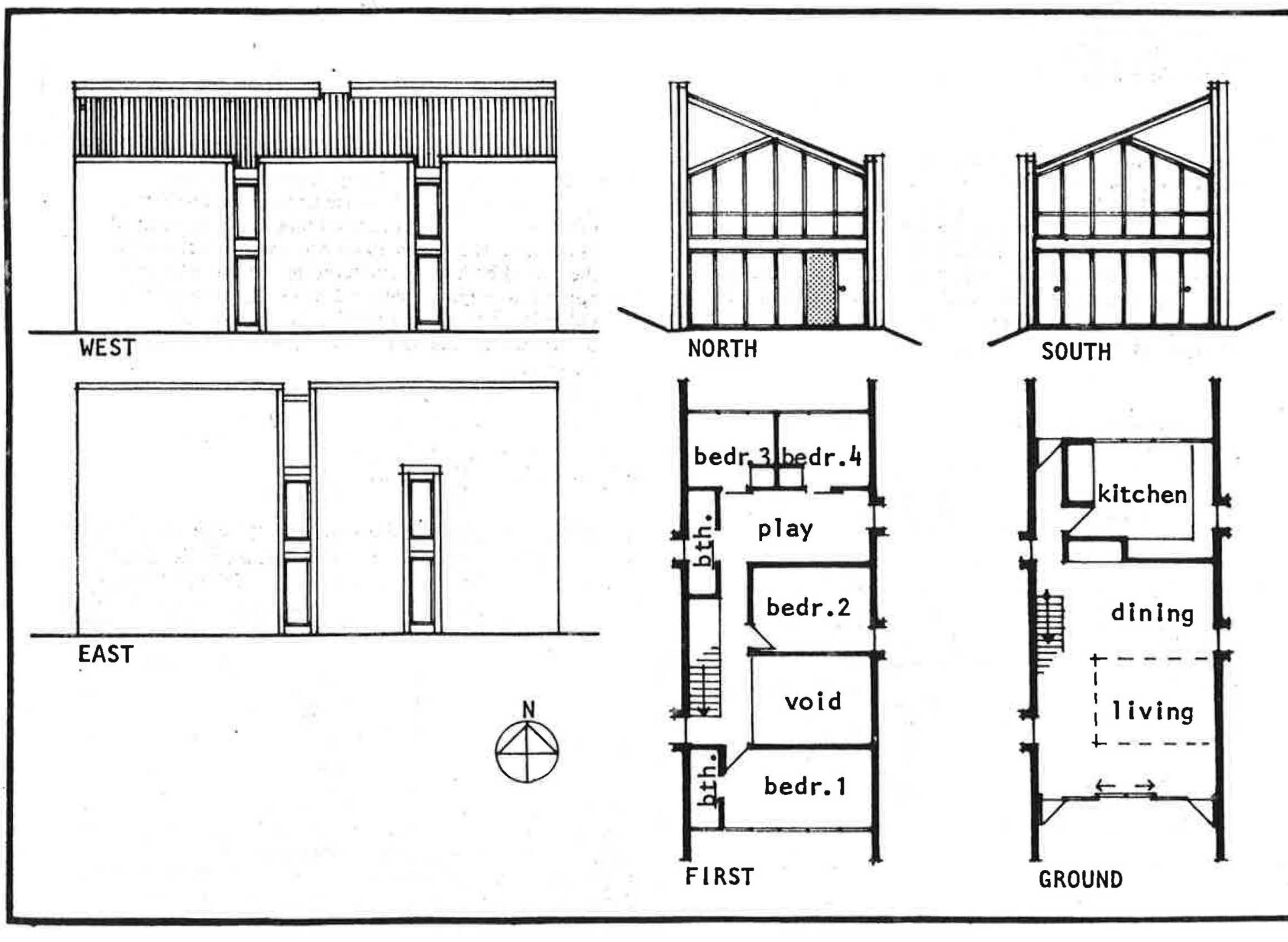


Fig. 6 House No. 4

House 2 - bronze medal winner in 1969 - is presented in Fig. 4. It is a single-storey, three-bedroom house. The western end has a concrete slab-on-ground floor, the remainder is a timber floor suspended over a gully. The western wall is cavity brick, otherwise it is timber framed with weatherboard cladding. Almost all of the north-east wall is openable and it has a 750 mm eaves overhang. The roof is a metal deck with a plasterboard ceiling. Maximum calculated ventilation rate is 45 air changes per hour.

House 3 - this won a citation in 1978 and it is shown in Fig. 5. It is a two-storey, two-bedroom house. The west and part of the north wall are precast off-form concrete panels, the remainder of the north wall is metal louvres, the south and east walls are mostly glass, supported on tubular steel trusses. Most windows face south. The roof is lightweight concrete on a "Bondek" steel permanent formwork, with a bitumenous membrane. The maximum calculated ventilation rate is 43.2 air changes per hour.

House 4 - shown in Fig. 6, also won a citation, in 1969. This is a two-storey, four bedroom house; concrete slab-on-ground, cavity brick walls and timber upper floor. The north and south walls are all glass. The roof is terracotta tiles with T & G boarded ceiling and internally exposed trusses. Maximum calculated ventilation rate: 56 air changes per hour.

It may be of some interest to compare the performance of these houses with that of an "ordinary" house. For this purpose one of the most popular house types has been selected (which has also been used in the validation study mentioned above)

House 5 - a Jennings house, shown in Fig. 1. It is a single-storey, three-bedroom house, with a concrete slab-on-ground floor, brick veneer walls and terracotta tiled room. Walls and ceiling are lined with plasterboard.

House 6 - a slightly modified version of house 5, incorporating some improvements, such as changing to cavity brick walls with brick partitions, including 50 mm insulation in the ceiling, improving cross-ventilation, moving the east and west facing windows to the north, adjusting the eaves overhang to allow some winter sun penetration, whilst providing full shading in summer and excluding morning and evening sun-penetration on south-facing windows by vertical fins (see Fig. 7). Maximum calculated ventilation rate: 72 air changes per hour.

Fig. 7 House No. 6: the modified Jennings house.

The Method

Two simulation runs were carried out for each of the six houses for one day of each month:

1. using 14th percentile temperature and radiation data, with a minimum ventilation rate (0.5 air changes per house) - for the assessment of underheating
2. using 86th percentile data, with the calculated maximum ventilation rate, - for the assessment of overheating.

The resulting indoor temperatures were printed out on a 12 months x 24 hours matrix, in a format suggested by Brealey (Ref. 2) after Olgyay (Ref. 6). In the first case the lower comfort limit temperature isotherm was plotted on this matrix and in the second case the upper comfort limit. An example of this is shown in Fig. 8. The number of hours of the over- and underheated periods were then calculated (i.e. the period within the comfort limit isotherm), as well as the cumulative magnitude of over- and underheating in Kelvin-hours.

The comfort limits were established according to the findings of Auliciems (Ref. 1), as 20°C and 28°C. However an air movement of 0.75 m/s will make 32°C acceptable. Therefore, for assessment of summer overheating, the 32°C isotherm is used.

The maximum possible ventilation rate was calculated on the following basis:

(a) the "effective aperature area" was first found for the purposes of cross-ventilation, as

$$A_e = \frac{A_1 \cdot A_2}{\sqrt{A_1^2 + A_2^2}}$$

(e.g. Szokolay, Ref.11)

where A_1 and A_2 are the inlet and outlet apertures respectively.

(b) the air velocity at the critical opening was taken as 1.5 m/s for two reasons: (i) any internal air velocity greater than this would cause annoying side-effects, (ii) meteorological data shows that 3 m/s is exceeded in all months between 10.00 and 18.00 h, i.e. during the period of highest temperatures (at other times the approx. average velocity is 2 m/s). An assumed 50% reduction was allowed for the effect of various obstructions, such as vegetation, window controls, flyscreens.

(c) the ventilation rate was taken as $1.5 \cdot A_e (m^3/s)$ thus the number of air changes per hour as

$$N = \frac{1.5 \cdot A_e \cdot 3600}{V}$$

where V is the volume of the ventilated space in m^3.

By this method the buildings as designed are evaluated. No allowance can be made for any deviation of the building, as built, from that specified, for the influence of user behaviour or for microclimatic effects caused by topography and vegetation.

Results

A summary of the simulation results is shown in Table 1. Fig. 9 gives a histogram of heating and cooling degree- (Kelvin) hours, i.e. the magnitude of underheating and overheating respectively. Fig. 10 shows the hourly temperature profiles for a typical winter (July) and summer (January) day.

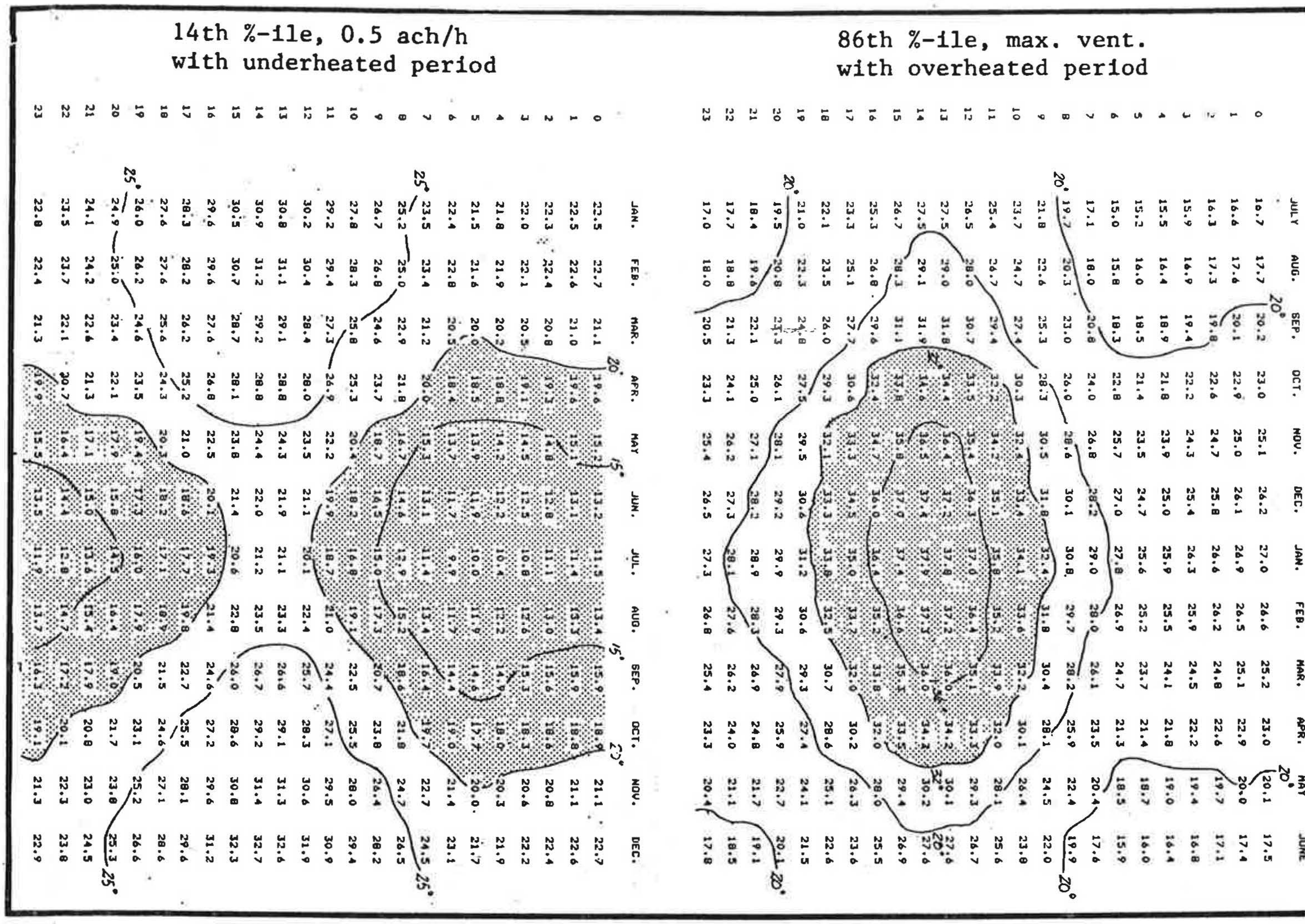


Fig. 8 14th and 86th percentile temperature matrices, with isotherms superimposed (house No. 3).

Table 1.

Thermal performance of six houses

	1	2	3	4	5	6
Summer:						
max.temp.reached (°C)	35.2	33.4	37.9	33.3	38.3	31.8
period overheated*(h)	33	13	54	11	62	0
overheated K-hours	50	9	157	4	165	0
Winter:						
min.temp.reached (°C)	10.7	11.6	9.9	11.7	10.2	13.3
period underheated (h)	114	102	102	115	118	112
underheated K-hours	456	337	444	400	427	327

*out of a 288-hour (12 mths x 24 h) year

Discussion

The first striking feature of Fig. 9 is the magnitude of underheating, compared with overheating. It is obvious that the preconceived idea of Brisbane being a hot place dominates the designs and the winter condition is usually neglected.

House No. 3, performs the worst. This is particularly visible from Fig. 10: in July it is both coldest and warmest, it has the widest amplitude (9.9°C to 21°C, i.e. 11.1K) and in January it is the hottest (37.9°C), with an amplitude of 12 K. If the building is examined, the probable causes can be readily identified:

- the extensive glass areas and metal louvres have very little thermal capacity, so the thermal response is fast.
- the large windows on the east side admit a very substantial solar gain in the morning hours (in January also the south