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BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

REPRINT No.7 **AUGUST 1978**

ACCOUNTING FOR WINDOWS IN BUILDING HEATING ENERGY CALCULATIONS

PRESENTED AT: N.Z.I.E. ANNUAL CONFERENCE,
HAMILTON, N.Z., FEBRUARY 1978

NZIE CONFERENCE HAMILTON 1978

BUILDING SERVICES GROUP PAPER NO. 10.

ACCOUNTING FOR WINDOWS IN BUILDING HEATING ENERGY CALCUATIONS

ABSTRACT

A study, of which this paper is a part, has been undertaken to provide a data base, and technique, for simply estimating design-sensitive heating energy requirements of buildings. In this paper, window heat gains and losses alone are investigated by studying over a five year period, the dependence of two variables:

1) Solar heat gain
2) Conducted heat loss

on the yearly, seasonal and hourly weather pattern, and window orientation. The principal findings are as follows:

1) A data base permitting superior building energy use estimates to be made, using the heat loss factor method, is practical and will soon be available.

2) Expanding the database to other New Zealand centres is simplified by the results of this study.

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1. INTRODUCTION

The degree day method (ASHRAE 1976) has been widely used for calculating the heating season fuel requirements for buildings. Its advantage is a very desirable simplicity which follows from describing the climate with only one variable; the degree-day value. Limitations become evident when the heating energy is required to be sensitive to building design changes, for example a reduction in the size of south-facing windows. This has not previously been possible since the contribution of solar radiation is approximated in a way which leaves the calculated result insensitive to window size and orientation. In addition, the significance of surface colour and hence solar absorptivity is not considered.

The new ASHRAE "Handbook of Fundamentals" is expected to promote alternative ways of calculating winter heating energy requirements which are more sensitive to the weather pattern and the building specification, yet retain the desk calculator simplicity of the degree-day method. A beginning has already been made in Canada where Mitalas 1976, has prepared graphical heat loss factors for windows in a selection of orientations and exterior walls of different colour. Using this data the winter heat loss is separately worked out for each exterior surface as the product of the appropriate "heat loss factor" and the module area. The degree-day value, and the latitude are retained only as a way of characterising the climate.

With similar developments in mind for New Zealand, we are looking at the variability of building climate variables with time and direction: with a view to providing a useful data base for design sensitive winter heating energy calculations. The work described in this paper deals exclusively with solar heat gains and conducted heat losses from windows.

2. DESCRIBING WINDOW HEAT TRANSFER

The degree day method for estimating winter heating requirements does not separately resolve the influence of windows but this can be independently achieved from a knowledge of two variables:

1) Window solar heat gain = S W/m^2
2) Conducted heat loss = Q W/m^2

The first of these includes the total solar energy gain through a sheet of clear glass from direct and diffuse solar radiation, together with a ground reflected component of usually 0.2. Where a window is tinted or shaded internally the solar gain is simply a product of the shading coefficient and S. The effectiveness of geometrical external shades depends on the sun's position, and simplified design rules exist for accounting for the common types, e.g. horizontal overhang.

The conducted heat loss term encompasses all the window heat transfer remaining after the dominant solar radiation transmission has been removed. In this case it is evaluated as:

$$Q = (20 - T\ )/R \qquad (1)$$

where T = window sol-air temperature

R = total window thermal resistance = $0.21\ \frac{m\ .k}{W}$

20 = Indoor temperature chosen for the study

Unlike degree day figures, the Q term can easily be corrected to a different indoor temperature T' via the relation:

$$QT' - Q20 = (T'-20)/R \qquad (2)$$

Furthermore, the value of R can be changed to model the effect of double glazing or curtains on the conducted heat loss via the relation:

$$Q^1 = \frac{Q\ R}{R^1} \qquad (3)$$

3. WINDOW CLIMATE DATA FOR WELLINGTON

SOLAR HEAT GAIN

The solar heat gain changes in a fundamental way with window orientation, season and time of day. A year to year random weather effect is also expected and we hope, and indeed find, that the variability this causes is small compared with the more fundamental effects. Having only five years of data available for this study places some restriction on the confidence with which we talk about year to year variation, and the confidence limits derived from this variability should be treated as approximate. Further conclusions from an analysis of variance study are enumerated as follows:

1) A useful simplification can be made by reducing the monthly data into three seasons defined as follows:

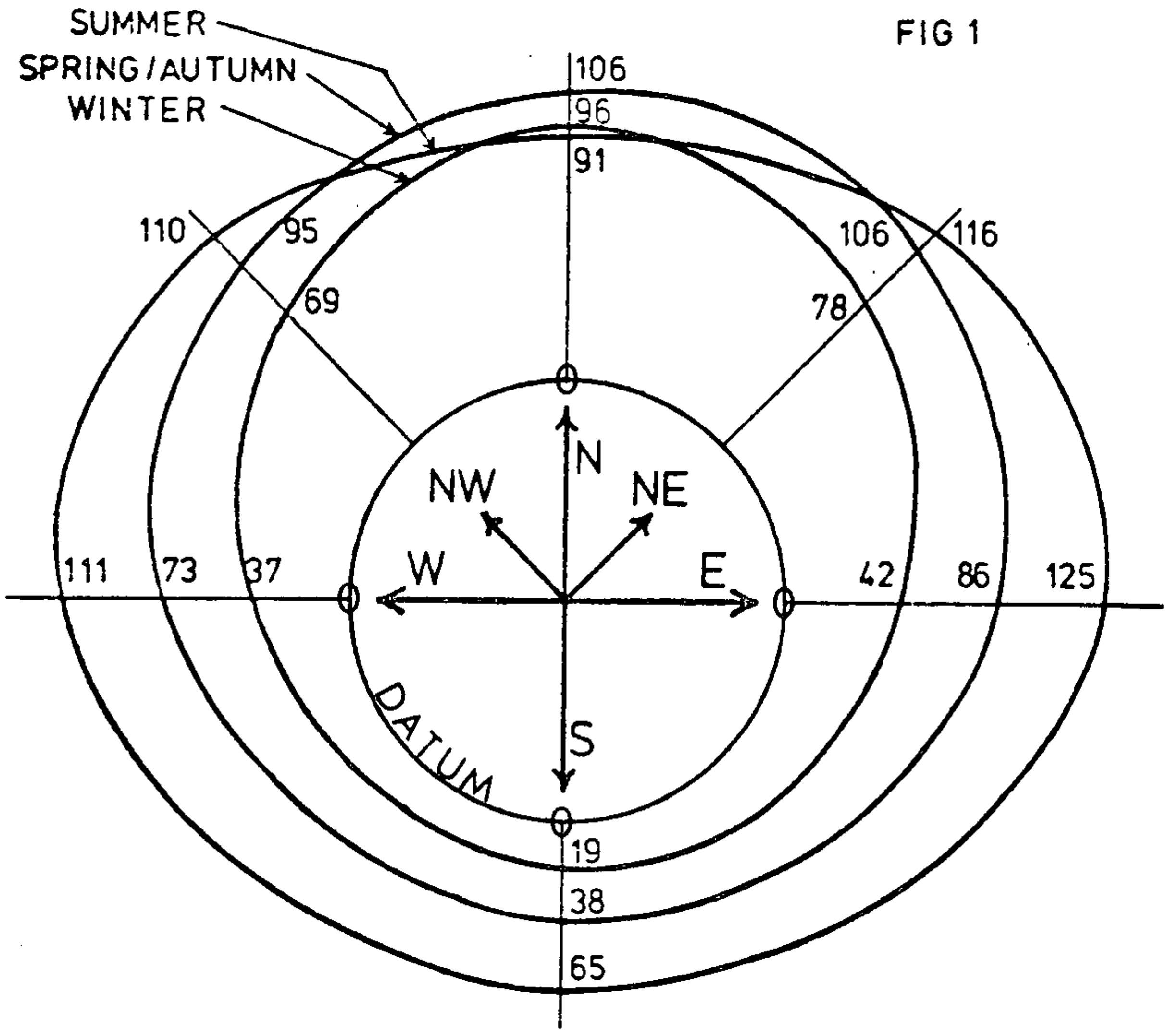
Summer = January, February, November, December
Spring/Autumn = March, April, September, October
Winter = May, June, July, August.

Most of the monthly variation is accounted for by this move and we present in Fig. 1 the season mean value of the window solar gain, plotted against orientation. The 95% confidence limit on these means accounts for the observed year to year variation.

SEASONAL AVERAGE SOLAR HEAT GAINS FOR CLEAR GLASS WINDOWS IN WELLINGTON

UNITS W/m2

FIG 1



APPROXIMATE 95% CONFIDENCE LIMITS TO MEAN ± 12 W/m2

2) The proportions of solar radiation gained through windows in different orientations change very little within a season. This means that design "weightings" for proportioning window areas are largely independent of the random weather variation within seasons.

CONDUCTED HEAT LOSS

As with the window solar gain, the conducted heat loss potentially depends on the season, time of day, window orientation and year to year weather variability. As with solar gain, an analysis of variance has been undertaken to give some numerical value to the importance of each interaction. The conclusions are as follows:

1) As with solar gain, most of the month to month variability can be accounted for as a seasonal effect.

2) The year to year variation of the monthly pattern is not systematic and is used to provide 95% confidence limits on the season means. These season means are as follows:

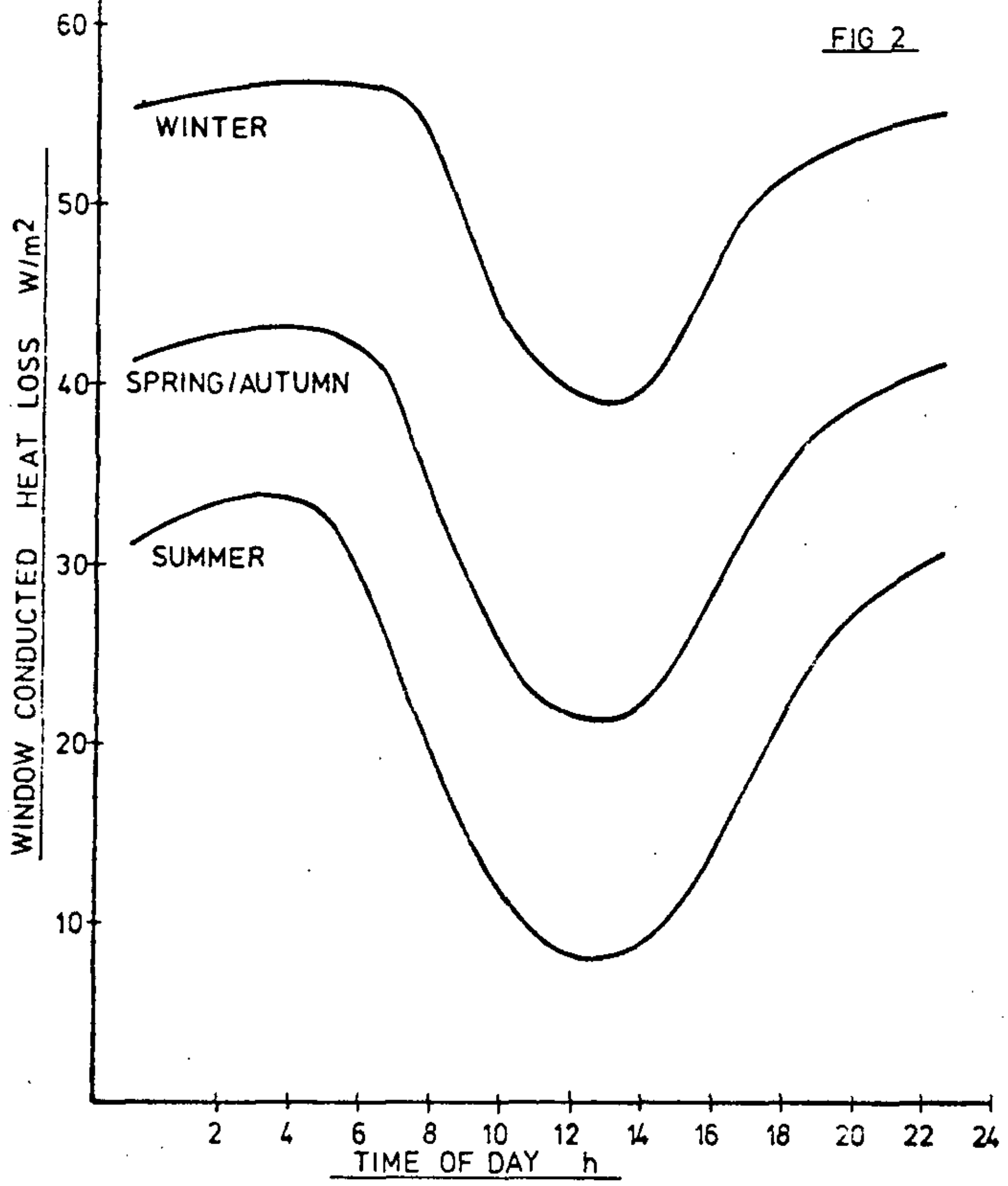
Season	Mean Window Heat Loss
Summer	22)
Spring/Autumn	35) ± 2 W/m^2
Winter	51)

3) The strong hour variation is mostly a result of the day-night cycle in ambient temperature although wind and longwave radiation effects are included. These seasonal hourly averages are presented in Fig. 2 for general interest.

SEASONAL HOUR AVERAGE HEAT LOSS THROUGH SINGLE GLASS WELLINGTON WINDOWS

UNITS W/m2 INDOOR BASE TEMPERATURE 20 °C

FIG 2



APPROXIMATE 95% CONFIDENCE LIMITS ON HOURLY MEAN ±4 W/m2

4) Window orientation has little effect on the conducted heat loss, a fact which is not surprising since the only orientation dependent term in the expression used to calculate Q is the 6% solar absorption term.

4. WINDOW HEAT BALANCE

Hour by Hour Resolution

The window solar gain and conducted loss combine to form a picture of how windows contribute to the energy requirements of buildings. In Fig. 3 we show the average seasonal hour by hour heat balance for windows facing E, NE, N, NW and W. Several interesting observations can be formed by comparing this average seasonal data with equivalent figures calculated for a clear day:

1) The average heat balance for north facing windows during the summer is little different from the clear day value. In winter, the average changes little from the summer average, yet the clear day value is much larger. These differences arise because the average summer gain is largely from diffuse radiation, where in the winter, direct radiation is a major contributor.

2) For east and west facing windows the seasonal contrast for average data is similar to that displayed by clear day heat balance values.

3) The asymmetry between east and west has been noticed before and during the five year period that these data represent, is caused by a tendency toward cloudy afternoon.

In a previous study Bassett 1976, the accuracy of the algorithms used to calculate the solar gain component was tested by a comparison with measurements made directly. The algorithms which calculate solar gains from relatively simple climate observations are shown by this study to be sufficiently accurate.

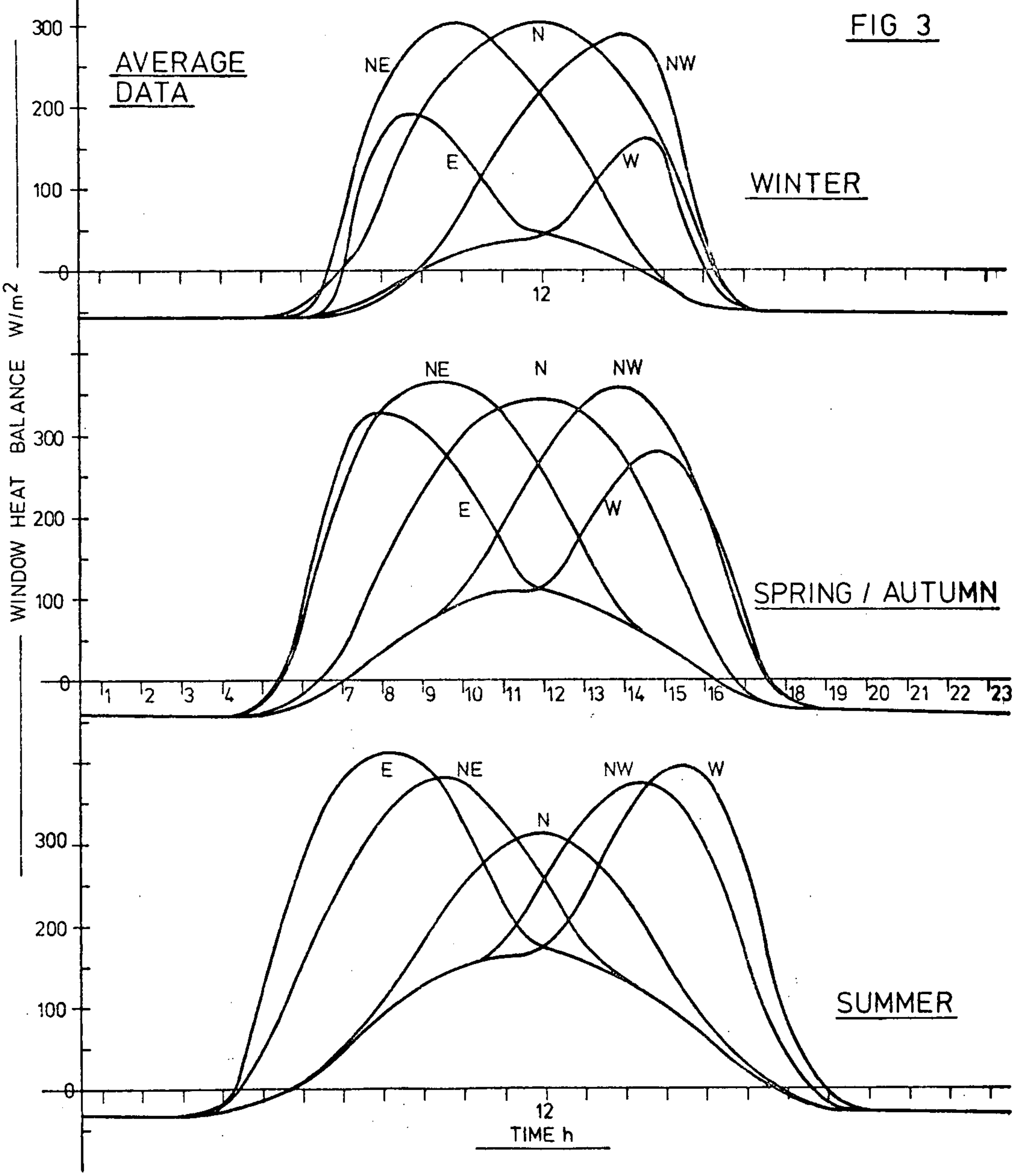
HEATING SEASON LOSSES

A modification of the traditional degree day method has been developed by G.P. Mitalas 1976 for estimating the winter heating requirement of buildings in Canada. Called the "Net Annual Heat Loss Factor" method, it separates the total building heat loss into four components:

1) window heat loss
2) opaque wall and ceiling heat loss
3) air infiltration - ventilation heat loss
4) below ground heat loss.

HOUR PROFILES OF SEASONAL WINDOW HEAT BALANCE FOR WELLINGTON

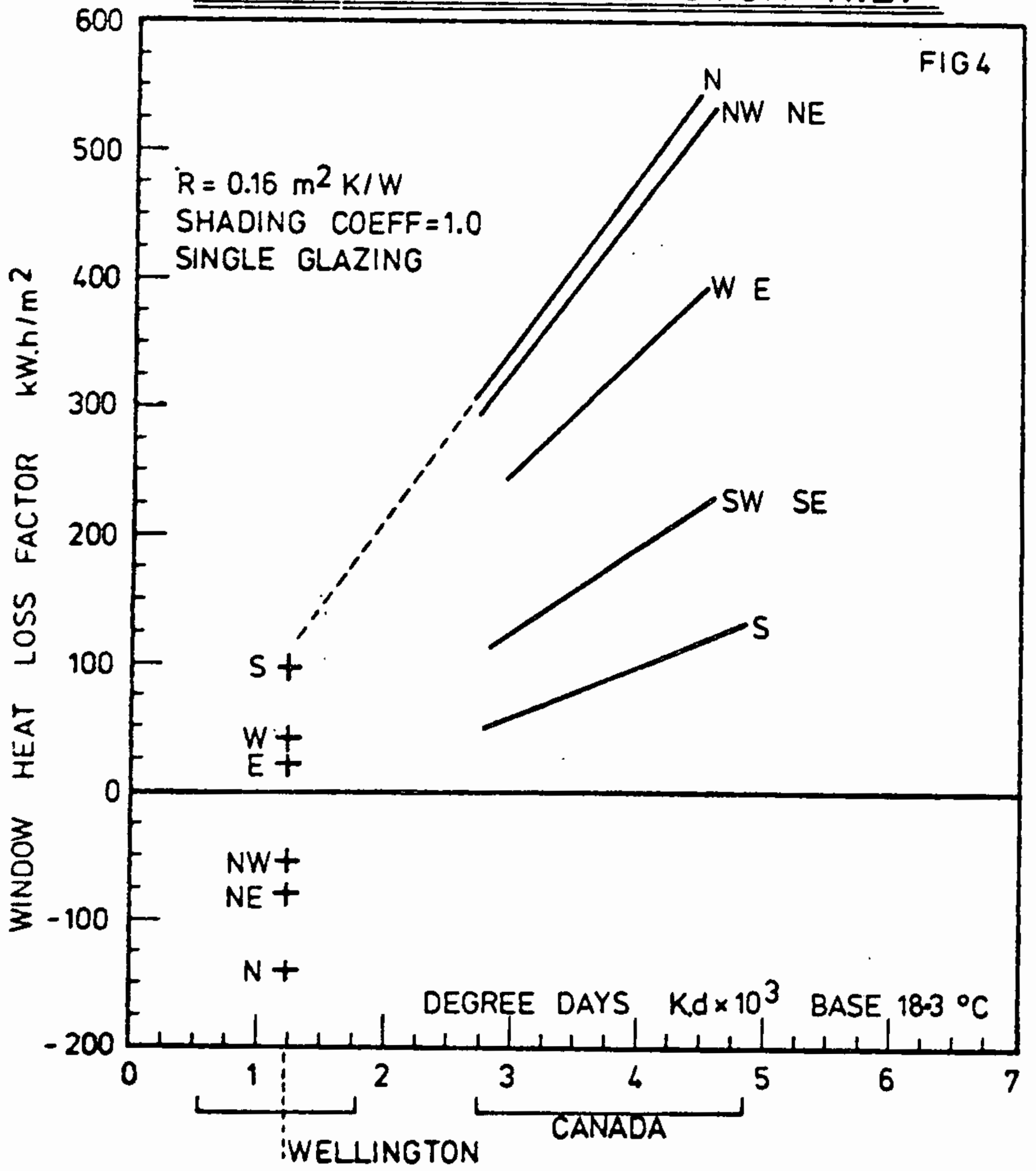
FIG 3



Each contribution is calculated separately as the product of the module area and a tabulated heat loss factor. Unlike the traditional degree-day answer, this product of four heat loss terms is sensitive to the building shape, and is hence useful as a design aid.

In the Canadian climate the window heat loss factors correlate quite well with the number of degree days for the various localities, although the localities have different latitudes and different types of climate. For this reason the degree day figure is used to characterise the climate in Fig. 4, on which we have added comparable data for Wellington.

WINDOW HEAT LOSS FACTORS FOR CANADA AND WELLINGTON N.Z.



It could be that latitude correlates more accurately with New Zealand heat loss factors since the variation in solar energy from north to south will probably dominate over the change in average ambient temperature and heat loss. For the moment all that can be observed is the correlation between the heat loss factor for windows not exposed to direct sunlight, and the degree-day value.

The Canadian north and Wellington south heat loss factors depend linearly on the degree day value as expected, since the solar gain component is small compared with the conducted heat loss. Similar extrapolation does not hold good for the other window orientations since the higher latitude of New Zealand means that solar gains are much higher than for Canada.

5. CONCLUSIONS

This study of one New Zealand location, reaches conclusions about the requirements of a data base for estimating the effect of windows on the heating requirements of buildings. It follows upon the heels of a previous study which tested and provided support for the algorithms used to determine solar heat gains from the available meteorological record. An analysis of variance of five years computed data was used to test the validity of several useful approximations which reduce the bulk of data, and simplify the data collection job for other New Zealand centres. The important conclusions are as follows:

1. A data base permitting superior energy use estimates to be made, using the heat loss factor method, is practical and will soon be available.
2. Expanding this data base to other N.Z. centres will be simplified by the following:
    a) The seasonal variation of window heat transfer can be adequately described with three seasons.
    b) The orientation dependence of conducted heat loss is insignificant.
    c) The pattern of solar heat gain with orientation varies little within each season, compared to the absolute value of the solar gain.

APPENDIX

COMPUTER CALCULATIONS OF WINDOW CLIMATE DATA

The building climate data in this paper was generated by the dynamic heat transfer program SUSTEP using hourly climate data NOV 1969 - OCT 1974 collected and made available by the Meteorological Service.

The calculated data was generated by specifying a building consisting of a single window and wall facing a specified direction, together with a flat roof. The indoor air space was thermostatically controlled to 20°C and the energy requirements of the heating and cooling plant interpreted as the window energy balance. Wall and roof modules were specified with a large thermal resistance and zero capacitance to avoid interacting with the indoor energy demand.

Clear single glazed windows were specified with the following optical and thermal properties:

Solar transmittance	0.86	
Solar absorptance	0.06	
Solar reflectance	0.08	
Indoor film resistance	0.14	m^2K/W
Outdoor film resistance	0.07	m^2K/W
Thermal capacitance	7.0	kJ/m^2K
Thermal resistance	0	
Long wave emittance	0.9	
Shading coefficient	1.0	

The following references are useful for explaining the method used to calculate window heat losses and gains from meteorological observations:

The method used for calculating low temperature radiation is based on "Surface Temperatures and Heat Fluxes for Flat Roofs" by Hoglund, Mitalas and Stephenson, Build. Sci., <u>2</u>, 29-36 (1967).

The method used for calculating solar altitude and azimuth is based on "Calculation of solar position for building purposes" by Spencer, DBR Tech. Paper No. 14, (1965).

The method used for calculating the radiation on surfaces with horizontal sunbreaks is based on "Solar Radiation incident on building surfaces and solar heat gains through windows" by Ballantyne and Spencer, Proc. Symp. on Environmental Physics as applied to Buildings in the Tropics, Vol. 11, CBRI, Roorkee, India (1969).

The method used for calculating transmission and absorption of 3 mm thick flat glass is contained in ASHRAE Handbook of Fundamentals, 1972, p 398. A discussion of the shading coefficient concept is contained in the same publication, p 480.

ADDITIONAL REFERENCES

1. ASHRAE Handbook; 1976 Systems Volume. American Society of Heating, Refrigeration and Air-conditioning Engineers.

2. Mitalas, G.P. Net annual heat loss factor method for estimating heat requirements of buildings. National Research Council of Canada, Division of Building Research, Building Research Note 117, 1976.

3. Bassett, M. The wintertime heat balance of New Zealand windows. Building Research Association of New Zealand report R. 21, Reprinted from NZIE Conference, Dunedin, February 1976 Paper No. 29.