EDUCATIONAL BUILDING DIGEST 12
UNESCO REGIONAL OFFICE FOR EDUCATION IN ASIA AND OCEANIA
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THERMAL COMFORT: AN INDEX FOR HOT, HUMID ASIA

1. BACKGROUND

A comfortable environment comprises at least four main components: (1) enough light to see easily, (2) comfortable chairs and tables, (3) conditions in which pupils and teachers can hear each other speak plainly and (4) a climate that is neither too hot nor too cold. The architect's business is to ensure that in designing a space for teaching and learning, such as a classroom or a laboratory, the requirements for all these principal aspects of physical comfort are met.

In Asia, the work of Narasimhan and others (1) has resulted in the development of simple techniques that architects can use to design windows to give enough daylight on working surfaces. Choudhury and his colleagues have provided guidelines to assist architects to design for good hearing conditions (2). A great variety of data is now available to enable architects to design comfortable furniture (3). This Digest will, if used with certain other data that are readily available, assist architects to design educational facilities that are as thermally comfortable as is possible without recourse to mechanical air-conditioning.

2. THERMAL COMFORT

The sensation of thermal comfort can be described by reference to a simple scale of thermal comfort (called the ***Bedford*** Scale) as follows:

Where S the sensation

- S = 1 : much too cool
- S = 2 : too cool
- S = 3 : comfortably cool
- S = 4 : neither cool nor warm, hence comfortable
- S = 5 : comfortably warm
- S = 6 : too warm
- S = 7 : much too warm

Whatever the sensation of thermal comfort may be, it will be determined by a combination of four conditions, each of which may vary from hour to hour and from day to day. These conditions are:

a) The air temperature; (measured as dry-bulb temperature)

b) The humidity of the air; (measured as vapour pressure)

c) The rate of movement of the air; (measured as wind velocity)

d) The radiant heat; (measured as globe temperature)

Two important points have to be mentioned here. First, a change in any one of the four conditions will result in a change in the sensation of thermal comfort. Thus, if the air temperature drops, the thermal sensation will be one of more coolness. If the rate of movement of air drops, it will feel warmer. If all of the conditions change, it becomes difficult to predict what the net effect will be— cooler or warmer.

The second important point is the realization that the architect, in trying to design a thermally comfortable educational building, can only influence two of the conditions listed above; namely, the rate of air movement or 'wind speed' (v in graph A) and the radiant heat (***tg*** in graph C) inside the teaching/learning space. The temperature of the air and its humidity are difficult to change in hot, humid climates without using mechanical or other somewhat complex equipment.

This Digest will not explain in detail how to vary the rate of air movement or radiation in buildings. This has been discussed by Ishwar Chand (4) and P. Chandra and colleagues (5). Thus, if the architect knows the range of local humidities and dry-bulb temperatures in the area for which the building is being designed, the building can be made thermally comfortable by adjusting the wind speed and radiation inside the building to appropriate levels.

3. USE OF THE NOMOGRAM

The purpose of this Digest is to show how, given the humidity (*p*) and air temperature (*ta*), the wind speed and the degree of radiation that will provide thermally comfortable conditions within a building can be estimated.

The nomogram consists of three parts: graph A which determines the wind speed; graph B which shows the values of S as a comfort index; and graph C which determines the degree of radiation.

The daily, monthly and yearly range in air temperatures and the corresponding air humidity for any particular location can be obtained from published climatological data.

To obtain the value for vapour pressure from the given relative humidity and the dry-bulb temperature; refer to graph D. The found value for *p* is then to be used in graph C of the nomogram.

The problem facing the designer is how to deal with the two variables that can be controlled by design (wind speed and globe temperature) inside the building. Some of the possibilities in respect of wind include reducing its speed by obstructions in the building 'envelope' or increasing at selected places by reducing the area through which the air flows, thus increasing its speed—a solution employed by Le Corbusier in designing the administration building at Chandigarh, India. Globe temperature, being a measure of radiation from the internal surfaces of the building envelope, can be increased by using thinner materials or decreased by either providing insulation or shading the outside of the envelope from direct heat from the sun.

An example in the use of the nomogram

Supposing the available climatological data indicate that, at the most uncomfortable time of the day or year, the average temperature is 31° C (*ta* in graph A) and the humidity measured is 27 mm HG (*p* in graph C). To provide a thermally comfortable condition within the building the designer must establish a combination of wind speed through the building (*v* in graph A) and of radiation inside the building (*tg* in graph C) that results in an S value between comfort index of S = 3 and S = 5 (graph B).

This digest is based on the study *Thermal stress index for warm, humid conditions in India* by M.R. Sharma and Sharafat Ali. The study was published as Educational Building Report no. 14, now available at Unesco ROEAO.

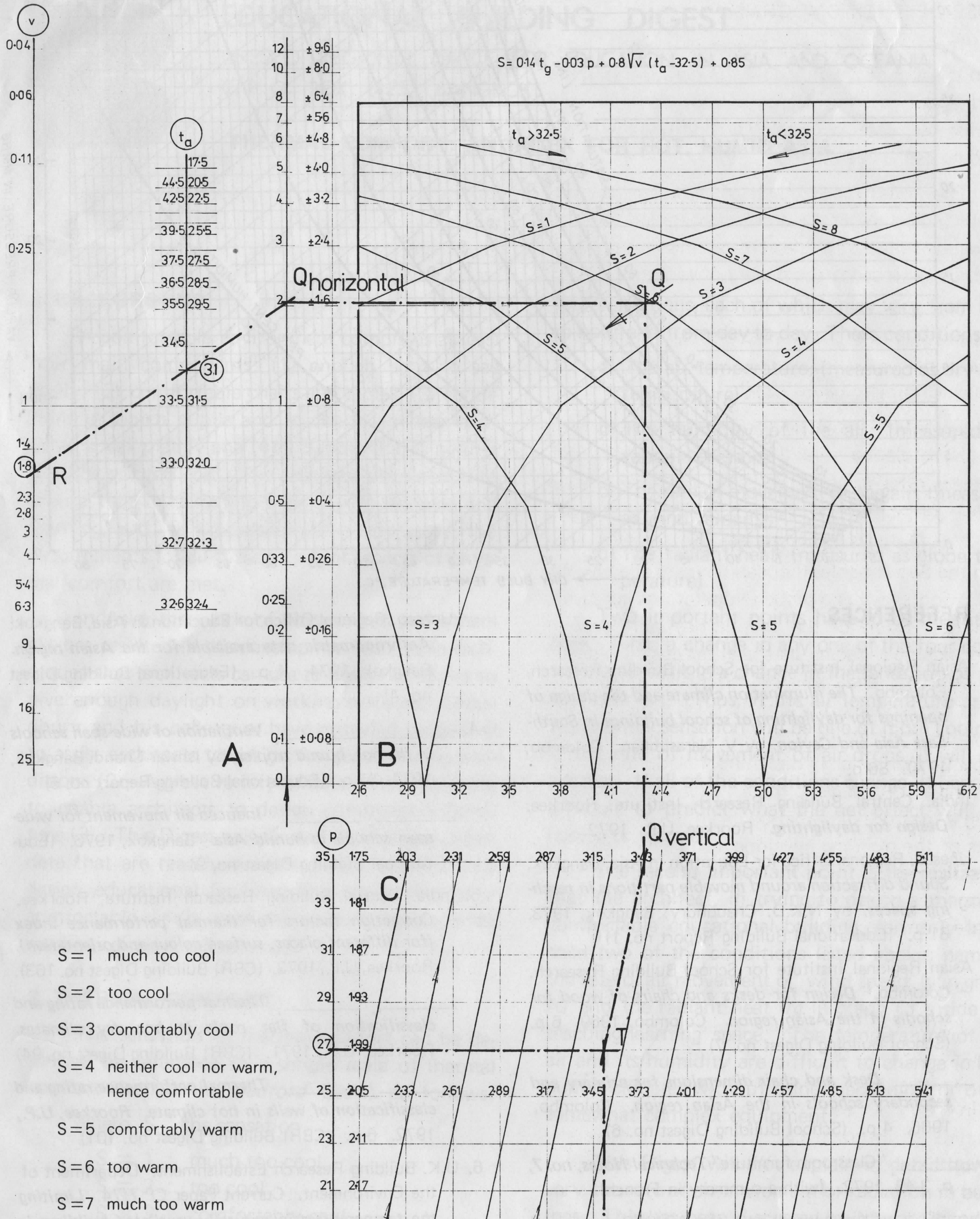
Take point Q on graph B anywhere near S=3, 4 or 5, and extend a horizontal line from Q to enter graph A at point Q horizontal, and extend a perpendicular line from point Q to enter graph C at point Q vertical.

The required wind speed is established by extending a line from point Q horizontal through the reading of 31 on the *ta* scale of graph A until it meets the scale *v* at point R, giving a wind speed reading of 1.8 m/sec. Should it not be possible to obtain this wind speed by means of window openings, or through proper orientation of the building in relation to wind, or through the planting of trees or shrubs, point Q will move down the line Q—Q vertical resulting in a warmer environment and a higher reading on the comfort index. Conversely, should a higher wind speed be the result, then point Q will move up the line Q—Q vertical pointing towards a cooler environment and a lower reading on the comfort index.

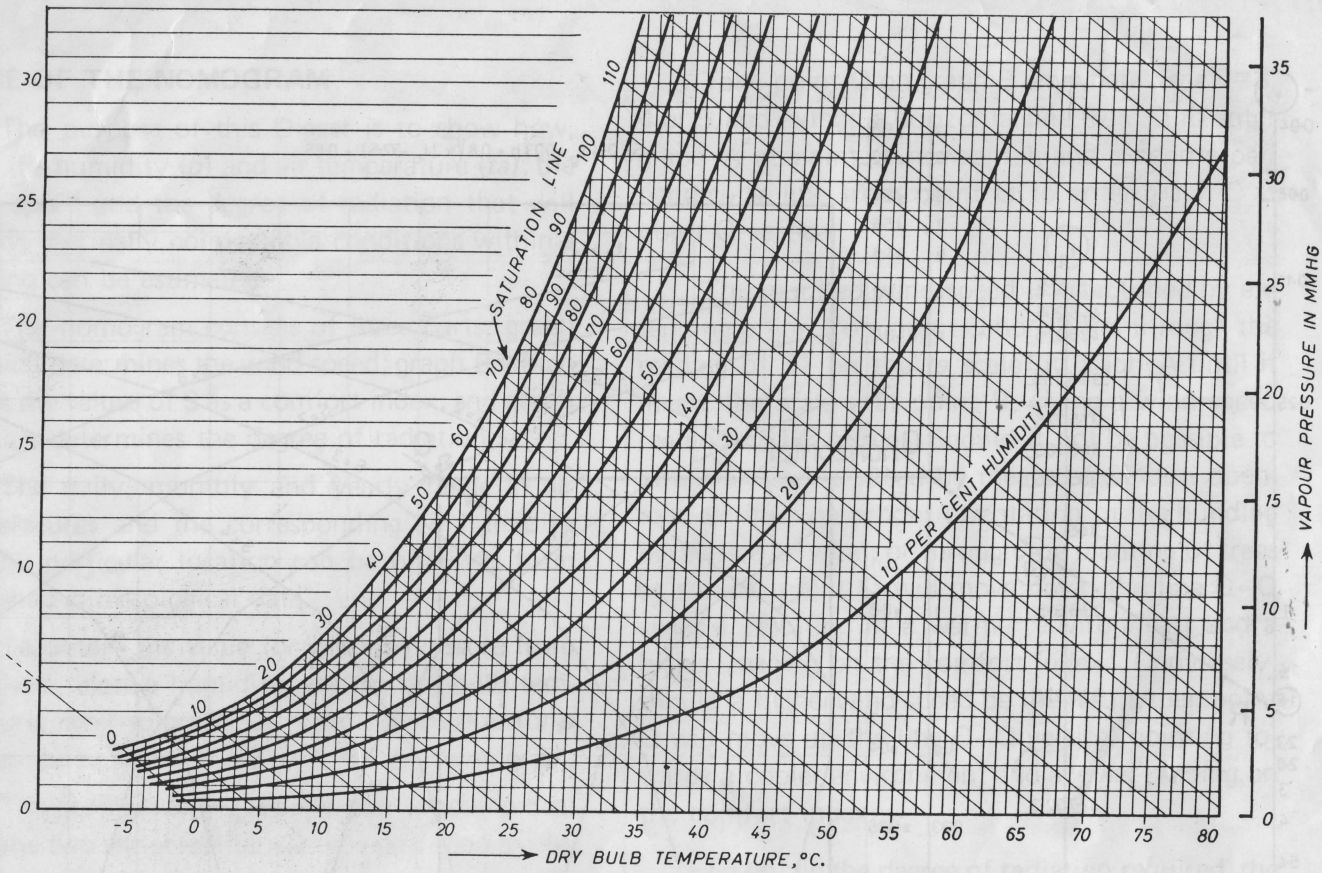
To obtain the degree of radiation required, the first step is to draw a horizontal line from the point reading 27 on the scale *p* in graph C. The second step is to extend a line, parallel to the sloping lines, from point Q vertical until it cuts the horizontal line, (point T); the third step is to extend a perpendicular line from point T until it cuts the scale *tg* giving a reading of 30.5° C. If such a value cannot be obtained by the designer, either because of the non-availability of suitable material or because of cost, a higher value on the *tg* scale will cause point Q in graph B to move to the right, indicating a warmer environment. A reduction in the radiant heat will cause point Q to move to the left and will result in a cooler environment.

An approach to the design of the building envelope, which relates the radiant temperature to the ventilation rate, is given by Petherbridge (6).

Countless combinations of the scales *v* and *tg* are possible, leading to a comfort condition between 'too cool' and 'too warm' and the designer must seek a compromise between how far wind speed can or should be controlled and how much insulation can or should be applied. Finally, the designer should concentrate on designing for a comfortable environment for the worst conditions during the time that the building is likely to be occupied (a school building may for instance be used only in the mornings) and not for the worst conditions at all times throughout the day.



S = 0·14 t_g − 0·03 p + 0·8 √v (t_a − 32·5) + 0·85
v
t_a
t_a > 32·5
t_a < 32·5
Q horizontal
Q
Q vertical
R
A
B
C
p
t_g
S = 1
S = 2
S = 3
S = 4
S = 5
S = 6
S = 7
S = 8
S = 1 much too cool
S = 2 too cool
S = 3 comfortably cool
S = 4 neither cool nor warm, hence comfortable
S = 5 comfortably warm
S = 6 too warm
S = 7 much too warm



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