ous resting conditions is shown in Fig. 2a, and the spontaneous activity is clearly in evidence. Fig. 2a demonstrates the existence of a number of frequency components spread throughout the frequency range associated with thermal vasomotor activity (0-0.1 Hz). However, when a suitable thermal stimulus (period of 20 s) was applied to the contralateral hand, the resulting power spectrum contained one dominant component at the stimulus frequency (Fig. 2b). This demonstrates the entrainment phenomenon. It was therefore established that the system could be entrained by a suitable 20 s stimulus (squarewave 18°-46°C).

Further experiments showed that stimuli of periods up to 80 s would entrain the system, while stimuli of a longer period would not. (Fig. 2c illustrates the power spectrum for a 120 s stimulus, and it can be seen that this spectrum closely resembles that of the spontaneous case, but with a small added component at the stimulus frequency.)

The object of the subsequent research was to establish the nature and operation of the control system, which would behave in a way illustrated by the different types of power spectra shown in Fig. 2, when operating under different conditions. Entrainment suggests the presence of a nonlinear element in the peripheral thermal system; a mathematical analysis proved to be compatible with this view, and the nonlinear element was considered to be of the ‘bang-bang’ type. Further, the mathematical analysis facilitated the synthesis of a suitable block diagram of the thermal vasomotor control system (Fig. 3). The computer model which was subsequently developed from the block diagram illustrated that the nonlinear element chosen enabled accurate simulation of the experimental results.

**Computer simulation**

There have been a number of attempts in recent years to simulate the human thermoregulatory system. These models can be divided into two broad types: mathematical models, which represent the body’s heat balance in terms of a single element; and those which describe thermoregulation in terms of the thermal interdependence of the various parts of the body.

A good example of the first type is that of CROSBIE et al. (1963). These authors developed a model that describes human thermoregulation by considering the body to comprise concentric cylinders of different types of biological material. Of the distributed models, the simulation proposed by STOLWIJK (1970) is certainly one of the most accurate. In this model, the body is divided into six segments, which interact thermally. A number of reviews of the subject have appeared recently; probably one of the best is that of LIANG–TSENG FAN et al. (1971), which describes most of the models published to date.

Unfortunately, these models are not capable of simulating dynamic vasomotor control in the human upper limb or the simulation of the conditions for entrainment. A different approach was therefore employed in the work described here.

As has already been stated, the primary objective of the research was the analysis of thermal vasomotor activity, particularly in the upper limb. The major site of vasomotor activity in the upper limb is the hand. In order to investigate changes in digit blood flow, it was important to design a computer model which was capable of simulating changes in the size of the blood vessels in the hand.
influence each other. These control systems have been called the core system and the peripheral system and are considered as second and first lines of defence, respectively.

The first line of defence (peripheral system) refers to the body's initial reactions in the face of environmental temperature change. The overriding algorithm of thermal control seems to be that heat should always be preserved in the core. Because of its role as a first line of defence, the efferent activity associated with this thermal control system is considered to be primarily vasomotor activity. Similarly, in this control system, the prime sources of afferent activity are the skin receptors. Thus, when a change occurs in the environmental temperature, the skin receptors detect this change, and the control system responds by producing the appropriate degree of vasoconstriction or vasodilatation. If these measures are effective, homeostasis will be maintained, and the core temperature will remain in a steady state. However, if such vasomotor adjustments prove to be inadequate, the thermal equilibrium of the core will be upset, and the receptors in the hypothalamus will presumably detect a change in temperature.

When the receptors in the hypothalamus detect a change in temperature, the so-called second line of defence is thought to be activated. By virtue of the fact that the thermal equilibrium of the hypothalamus has been disturbed at all, the degree of thermal stress must be significant, and the resulting efferent activity would therefore be likely to produce gross control actions such as shivering or sweating. On the other hand, the peripheral control system would be primarily involved in minimising the effects of environmental changes in temperature by adjustments in vasomotor tone.

Adjustments in vasomotor tone produce alterations in superficial blood flow, and these may be observed in the digit-blood-flow waveforms. BURTON and TAYLOR (1939, 1940) have investigated these digit-blood-flow waveforms in some detail and have managed to isolate certain spontaneous components, which they associated with thermal vasomotor activity. The investigation reported here has been concerned with the spontaneous vasomotor activity described by Burton and Taylor and the analysis of the associated peripheral thermal-control system.

A systems analysis of the peripheral thermal system has led to the hypothesis that the spontaneous fluctuations observed by Burton and Taylor are the consequence of a system nonlinearity and are subject to entrainment (MINORSKY, 1962), illustrated in the following way. The power spectrum of the digit blood flow in a healthy adult under spontane-