TECHNIQUES OF MEASUREMENT.

INTRODUCTION.

The objective in physiological experiments is to obtain an exact record, usually an electrical analogue signal, of some physiological event. Thus the two main requirements of any transducer system apply : that its presence shall interfere minimally with the event, and that its response, both static and dynamic, be adequate to follow the course of the event.

In physiological flow investigations, the problem of satisfying these requirements whilst gaining access to the desired site pose major difficulties in transducer development and usage; repeated demonstrations of this will occur in these lectures. It is a particular problem in man, where surgical access is usually not possible and safety is an important consideration. Short-term experiments on animals under anaesthesia, without recovery, are therefore very widely employed; but it must be remembered, particularly in relation to cardiovascular studies, that both surgery and anaesthetic agents may produce profound functional changes in the heart and blood-vessels.

The vast majority of transducers applicable in physiological experiments employ some form of probe applied to the site at which measurements are to be made. In some cases, where a degree of spatial integration is useful (e.g. electromagnetic flowmetry) the probe may be relatively large, but in the majority of cases information from a point source is more useful, and probe miniaturisation is further desirable to facilitate access to a system and minimise interference. Some transducers (e.g. thermistors, thin films) may be made extremely small, and built into a probe at the site of measurement. Such an arrangement has great advantages in recording dynamic events faithfully, and is being increasingly applied as transducer technology improves. In many cases however, the transducer is too large for direct application, and the probe then becomes a transmission link; a classical example is the catheter-pressure transducer system. The behaviour of such systems may be much more complicated than the behaviour of the transducer alone, since information may be distorted in transit through the probe, usually with loss of dynamic accuracy, and extraneous noise may enter the system. Since many physiological events, particularly in the cardiovascular system,are time-dependent, satisfactory use of such transducers involves careful direct assessment of the dynamic properties of the whole assembly as well as calibration of the static properties.

The interference which a transducer probe may produce is of several kinds. Firstly,it may alter local structure, by its presence, so that function is disturbed; an obvious example is the effect that a large catheter would have on pressure and flow within a small vessel. Secondly, it may distort an event by draining excessive quantities of mass or energy from it. A satisfactory probe must therefore be miniaturised, and offer a high impedance to this flow; it should be noted that such features may be incompatible with maximum dynamic measurement accuracy, and are largely responsible for the progressive complexity of modern recording systems.

Interference may also come from some reaction of the living system to the presence of a probe. Intravascular catheters, for example, present a surface of foreign material to the blood and may cause thrombus or clot formation, either in the vessel or in the catheter. Alternatively, their presence may cause spasm of the vessel wall, with both local and general disturbance and redistribution of blood flow, and contact with the heart-wall may disturb the rhythm of cardiac contraction. All these effects may cause distortion of the measured event.

Thus the assessment, application, and management of transducers is often the central problem in measuring physiological events, and in general modern amplifiers and recording systems, although they may contribute some noise to the final record, are rarely a cause of trouble and will not be treated in detail here.

The choice of suitable transducers is of course a problem common to many fields of study. It is probably less common, at least in engineering, to meet a problem in defining the physical dimensions and geometry of the system under study. This occurs frequently in circulatory and respiratory flow studies, and can rarely be solved by post-mortem measurements. The diameter of a blood-vessel, for example, is dependent on the pressure within it, and the state of contraction of muscle-fibres within its wall; it must therefore be measured during life.

In studies of flow in living systems, the need therefore arises to make a number of dimensional measurements in the living animal, both in order to interpret flow measurements, and to provide a basis for realistic physical and mathematical modelling. Such measurements are often obtained by means of X-ray techniques, in which radio-opaque materials are introduced into the system and used to outline it on still or cine X-rays taken in one or more planes.