A RADIATION POWER CALORIMETER AND A RADIATION FORCE METER FOR SMALL ULTRASONIC BEAMS*

H. VAN DEN ENDE
Division of Neurology, Henry Ford Hospital, Detroit, Michigan, U.S.A.

Abstract—This paper is concerned with techniques for the measurement of power output of medical ultrasonic applicators in the range of 0.02 to 2 W.

A calorimeter consisting of 12.7 mm dia. copper piping 20 cm long, filled with castor oil into which ultrasound is radiated is described. Comparison with another calorimeter is given.

The paper then describes a radiation force meter consisting of an aluminum conical float which is attached to a converted mA meter with an extremely fine strand of nylon. The strand is wound around and glued to a pulley which replaces the meter coil. All parts are submerged in water and surrounded by absorbing lining. A procedure for calibration is given. The meter is direct reading, has rapid responses, has been used for a number of years, is relatively easy to construct and the technique of measuring force differs from that employed previously (JAMES et al., 1960; KOSSOFF, 1964; HENRY, 1957; WELLS et al., 1963).

Acoustic outputs as determined by the two instruments based on physically independent principles agreed to within 10 per cent.

INTRODUCTION

In recent years, ultrasound has gained popularity in the treatment of Meniere's disease which is a disease of the organ of balance. (JAMES et al., 1960; International Vertibular Symposium, 1963; KOSSOFF et al., 1964; SJÖBERG and STAHELE, 1965; McGEE et al., 1963). Its method of application is to the vestibular labyrinth after first removing sufficient bone to gain access. The labyrinth is not opened leaving a very thin layer of bone separating the applicator tip from the fluids in the labyrinth when the ultrasound is applied. The purpose is to disrupt and destroy the tissue in the vestibular labyrinth without doing damage to tissue in the cochlea. The objective is to abolish the symptoms of the disease and to preserve hearing. Several generators and applicators have been specially designed for this purpose (KOSSOFF, 1964; JAMES et al., 1963) Two ultrasonic instruments were used in our laboratory for animal experiments, one was designed about 1954 by Federici in Italy (JAMES et al., 1960), the other was designed by Kossoff in Australia (KOSSOFF, 1964).

Total power output of applicators must be adjusted for proper value before ultrasound is applied. From the literature, one obtains the impression that it is difficult to measure power reliably (GORDON, 1962). This paper presents two new techniques of measuring power, one based on the caloric effect, the other based on the radiation pressure effect. These two effects are manifestations of independent physical principles so that one technique may be used to check the other (HENRY, 1957; WELLS et al., 1963).

The caloric method

This method makes use of the fact that ultrasound, when travelling through a medium, degrades into heat as it is absorbed by the medium.

The calorimeter of Fig. 1 was used by the Physics Department of the Bristol Royal Hospital in England about 1960. The body of this calorimeter is a mixture of epoxy- and tungsten powder. Ultrasonic beam power is
measured by dipping the applicator tip in the water-filled semispherical cavity and measuring the rate of change of temperature due to ultrasound absorption by means of a thermocouple. The heating element serves to calibrate the calorimeter. Electrical energy is then applied at a known rate and the corresponding change in temperature is observed.

A weak point of this calorimeter is that heat transfer from the applicator tip directly to the body may take place by conduction and by convection, whereas ideally this coupling medium should isolate the applicator tip thermally from the body and at the same time transfer the ultrasound.

An impression of the heat conductivity of this calorimeter may be obtained from Fig. 2 which shows how the temperature of the thermocouple changes with time as a result of the application of electric energy to the heating element at a rate of 36 W for a duration of 10 sec. The dashed curve is the actual response. The response of a theoretical ideal calorimeter with infinite heat conductivity and approximately the same heat capacity is indicated by a solid line. The conclusion is that the heat conductivity of this calorimeter is rather low.

Because of this, an entirely different type of calorimeter device was developed which more nearly meets the requirements of high heat conductivity, good transfer of ultrasonic energy and good absorption. This device is shown in Fig. 3. It has a copper tube 20 cm long and 12.7 dia., filled with castor-oil, and also a thermistor in a Wheatstone bridge arrangement to measure the temperature. Thermal isolation of the applicator tip and the calorimeter body is also a weak point of this calorimeter. At high intensities, the effect of a flow of heat directly from the Federici applicator tip to the copper tube could sometimes be noticed by a rather sudden change in the slope in the calibration curves.

Figure 4 shows the change of temperature vs. time as a result of the application of electrical energy at the rate of 47.6 W for a duration of 10 sec. The actual response is closer to the ideal response than that of the epoxy–tungsten calorimeter and it was felt that a good improvement had been obtained.