stimulation reflected the capacitance of the electrode-heart-electrode system.

4. These studies demonstrated that electrical cardiac pacemakers can produce ventricular fibrillation if a 2 msec. impulse of sufficient strength falls within the vulnerable period of the cardiac cycle. It is imperative, therefore, that cardiac pacemakers be set to operate at current values close to threshold to avoid the possibility of production of ventricular fibrillation.

SIMULTANEOUS VOLTAGE AND CURRENT WAVEFORMS GENERATED DURING INTERNAL AND EXTERNAL DIRECT CURRENT PULSE DEFIBRILLATION

K. WILLIAM EDMARK, M.D., F.A.C.S.

Defibrillation was first produced, with the use of a discharging capacitor, by the Russians Prevost and Battelli in 1899. Kouwenhoven, employing capacitor discharges, produced defibrillation, but in an unpredictable way. R. S. Mackay in 1960 made the important observation that the presence of a 1 henry inductor, in series with the capacitor, roughly halved the required energy for defibrillation. This suggested to us that the design of the inductor might be the critical element for capacitor defibrillation and not just the watt-second charge on the capacitor. Reduplicating Mackay's work, while the current and voltage waveforms generated across chest and heart of the dog were observed and photographed on a dual beam oscilloscope, resulted in the unexpected observation that most inductors saturated and produced ringing. Ringing caused violent body response and erratic defibrillation. A current waveform from a 30 watt-second capacitor discharge across the dog chest is shown in Figure 1. Note short rise time of 0.005 milliseconds. Erratic and unpredictable defibrillation occurs. A properly designed nonsaturating inductor produced consistent current waveforms, minimal or no body response and predictable defibrillation. Figure 2 illustrates the simultaneous current (top) and voltage (bottom) waveforms generated across a

From the Department of Surgery, University of Washington School of Medicine and the Pacific Northwest Research Foundation, Seattle, Washington. Supported in part by Public Health Service Grant H-3019.

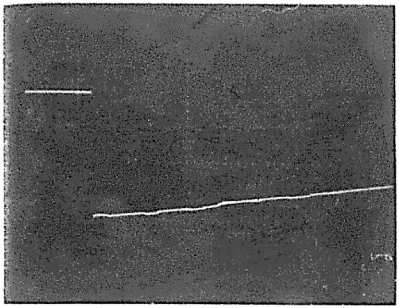

Fig. 1

dog's chest from a 30 watt-second capacitor discharge through such an inductor. Note rise time is 0.37 millisecond. In 23 cases of congenital and acquired heart disease since December 1961, internal DC pulse defibrillation has been employed at esophageal temperatures to 27° C. Defibrillation was produced at settings between 15 and 50 watt-seconds in children and adults respectively. Recently, in a 61 year old man with mitral insufficiency, defibrillation was achieved with a single 10 watt-second discharge at an esophageal temperature

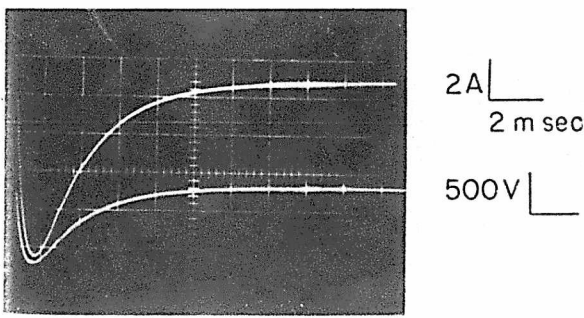

Fig. 2

of 28° C. Energy dissipated in the heart by a single 30 watt-second discharge is one-eighth that of a 0.25 second 220 volt AC discharge.

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VERTICAL BUBBLE OXYGENATOR WITH BUILT-IN HEAT EXCHANGER REQUIRING NO ADDITIONAL PRIMING VOLUME FOR TOTAL BODY HYPOTHERMIA

ROBERT H. GOETZ, M.D., M.B., CH.B., M.R.C.P., F.A.C.S., PAUL VILMOS, M.D., ELIZABETH MALLONGA, M.D., VERENA M. GOETZ, M.D., AND DAVID C. KRIPKE, M.D.

With the increase of open heart surgery, the collection of large amounts of blood required for priming the heart lung apparatus presently employed in many clinics has become an intolerable burden on both the surgical staff and blood bank. The addition of conventional heat exchangers further increases the priming volume and the surfaces with which the blood comes into contact. The introduction of the hemodilution principle for total body perfusion has further accentuated the need for compact equipment requiring a small priming volume.

Figure 1 illustrates our modification of the stainless steel bubble oxygenator incorporating an efficient heat exchange system which does not increase the priming volume and offers no additional surfaces to the circulating blood. Heat transfer takes place as the blood rises in the central bubble chamber and while it is running down the helix into the arterial reservoir. To achieve this, the helix has at-

From the Department of Surgery, Albert Einstein College of Medicine, Bronx, New York. This work was supported by Grant 3743-05 from the National Institutes of Health, an American Cancer Society Institutional Grant and an Investigatorship of the Health Research Council of the City of New York, under Contract I-237.