The Extra Cardiac Pacemaker
A Canadian Invention and an IEEE Milestone

By Visda Vokhshoori

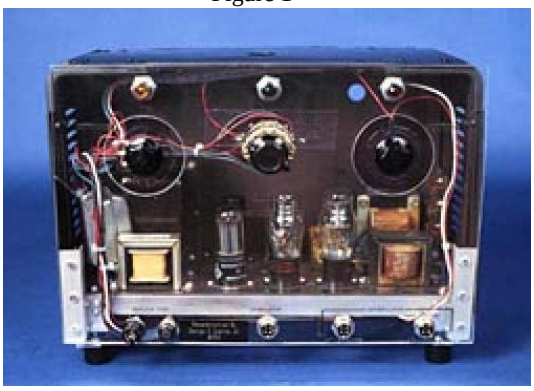
1.0 Introduction

"There was no intent to sit down and develop a pacemaker. So often happens one piece of research spins off to something else." These are Dr. Hopps' words from his 1984 interview with panelists of CBC quiz show "Front Page Challenge". [1]

The development of extra cardiac pacemaker came about during Dr. Hopps assisting Dr. Bigelow in the study of hypothermia, cold surgery. During the studies, which took place in Toronto, the doctors realized that one of the problems is to keep the heart beating in the cold state. So they developed a technique to stimulate the heart, to keep it going.

In 1950, Dr. John Hopps designed the first catheter electrode for cardiac simulation. Hopps' Pacemaker-Defibrillator, as seen in Figure 1, operated on a vacuum tube. About a decade later transistors replaced the vacuum tube. This resulted in considerable decrease in the size of the pacemaker. Overtime advancements in transistor and battery technology have helped develop an implantable pacemaker in the humans.

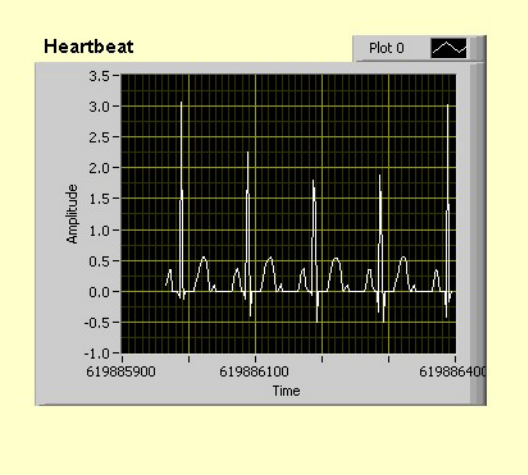
Figure 1 [3]



2.0 The Pump

The human heart is the center of a complex system designed to help the body nourish its organs with life-giving oxygen and to remove waste products in the form of carbon dioxide from the body. A healthy heart beats about 70 times a minute. It regulates its own activities, beating more rapidly during times of increased oxygen consumption and more slowly during rest and sleep. A heartbeat, an electrical impulse traveling through the heart, causes the cardiac cells to depolarize and contract. It is a four-part cycle consisting of contraction (systole) and rest (diastole) of upper and lower chambers. A heartbeat may seem like a simple event repeated over and over. As simple as it may seem, it is in fact a series of very complicated and precisely coordinated events that take place inside and around your heart. When the cycles are precisely timed, the heart is able to pump very effectively.

Figure 2

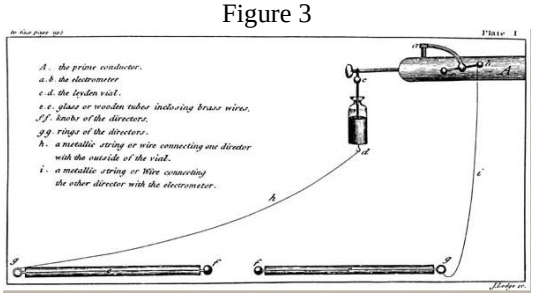


As you can see in the figure above, there are four parts in each cardiac cycle. The first peak indicates the start of the electrical impulse generated by the hearts natural pacemaker, sinoatrial (SA node). This area, (P wave), is smooth and positive and usually lasts less than 0.12 seconds. This is followed by a valley-peak-valley, otherwise known as QRS complex. QRS complex, in simple terms, is the definite indicator of a heartbeat. During the 0.04-0.12 seconds that it takes, the ventricles depolarize. From the bottom of the valley to the onset of the next peak, no electrical activity is recorded, hence the flat line. However, during this period the ventricles are contracting. The last part, T wave, represents repolarization or recovery of the ventricles.
At times the natural pacemaker may be defective, causing the heartbeat too fast, too slow, or irregular. The artificial pacemaker helps the heart to beat in regular rhythm. [2]

3.0 Pacemakers prior to Hopps

Beginning in the eighteenth century, physicians realized that electrical stimulation could cause muscles to contract - and they knew perfectly well that the heart was a muscle. **Charles Kite** recommended in "An Essay Upon the Recovery of the Apparently Dead", (London, 1788), electrical discharges to the chest for resuscitation. Kite's invention was more of a precursor to defibrillation, than to pacing.

Figure 3

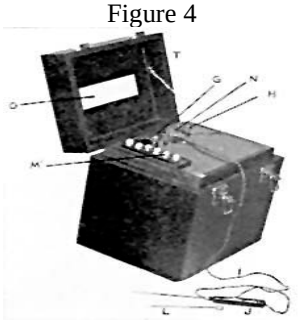


The apparatus as shown in Figure 3 is from Kite's article. An electrostatic generator charges a Leyden jar capacitor, which can discharge its accumulated electrical energy through the electrodes below. Energy will build up until the voltage is high enough to jump the spark gap.

The idea of the "pacemaker" is attributed to Dr. Albert Hyman of New York. Hyman's apparatus, based on his notes dated April 6, 1930 [4], included

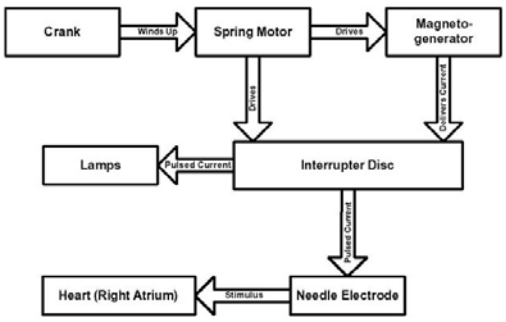
(1) a small source of electric current, i.e., a common flashlight battery;
(2) an interrupter mechanism;
(3) a timing device;
(4) a method of regulating the duration of the injected current; and,
(5) a suitable insulated needle to carry the current only to the right atrial area of the heart. The instrument would, of course, be easily portable, and small enough to fit into a doctor's bag.

Figure 4



In Figure 4, you can see the flow diagram of Hyman's pacemaker. The electrical current needed, was supplied through winding the hand crank attached to a spring motor which drove a magneto-generator and produced the desire current. Each time this current came into contact with the disc interrupter an electrical surge passes to the needles and then to the heart.

Figure 5



Flow Diagram of Hyman Pacemaker

Diagram detailing how the spring-wound Hyman pacemaker produced stimulii.

One major problem cited with this design was the uneven pulse rate that resulted from having to rotate the crank to generate the current. It is believed that Hyman tested this instrument on animals only. [4] [5]

4.0 Hopps' Pacemaker Circuit

The end of world war promised new beginnings. Interest in hypothermia began in that era when the need for amputation was realized. It was while studying hypothermia at NRC that John A. Hopps acquired the high-frequency heating that would lead him to make the first artificial cardiac pacemaker.

In the pacemaker model, Hopps developed, he utilized
(1) stimulator-difibrillator;
(2) foot padel Micro Switch;
(3) Two Electrodes/Foot Pedal that allowed surgeon to control flow of electricity while positioning electrodes by hand on either side of the heart. [5]

The pacemaker was large, 30 cm long and several centimeters wide and high. The unit was powered by 60 Hz household current.

Figure 6

Dr. Hopps, testing a pacemaker

When transistors were invented Hopps' pacemaker idea was incorporated into a smaller unit. Hence the first implantable pacemaker was invented in 1958.

5.0 Pacemaker Advancement

Today the pacemakers are small, compact, mini-computers that are implanted in human's body to keep heart beat in regular rhythm. The advancement in the battery design has made a tremendous difference in the life

of a pacemaker. Unlike, the first implanted pacemaker that lasted only one day before the batteries conked out, today pacemakers can last up to ten years.
The first major technological leap in pacemakers occurred when pacemakers stopped just pacing the heart to a preset rhythm and started to offer more "intelligent" therapy.
. Sensing is the function that allowed pacemakers to "listen" to the heart and literally record what the heart was doing on its own.
Pacemakers quickly adopted computer and microchip technology to add "brains," so that they were equipped to listen to the heart, "make a decision", and then pace or not. Modern pacemakers monitor every beat of the heart and "fill in the missing beats" when the heart does not beat as it ought to. When nothing is needed, the pacemaker merely observes, content to be on stand-by.

Another major advancement in pacemakers occurred with the so-called transvenous lead. Transvenous means "through the vein", and lead is the standard term for the insulated wire that runs from the pacemaker (usually implanted in the upper chest) to the heart itself.

While remote patient monitoring is becoming increasingly sophisticated, pacemakers were actually some of the original devices to offer telemedicine. Even as far back as the 1980s, pacemaker people could send information from home to the doctor's office over a regular telephone. That technology is still around today, although with some refinements. In fact, pacemakers were some of the very first devices to introduce the whole concept of having a "check-up" with doctor and patient in two different locations!

The pacemaker business is still going strong. Millions of people all over the world have benefited and continue to benefit from this life-enhancing therapy.

6.0 Registration of the Pacemaker as a Milestone

Due to its significance and strong ties to Toronto area, IEEE Toronto Section nominated Development of “First External Electronic Cardiac Pacemaker with Internal Electrodes for Continuous Clinical Use” as its first IEEE Milestone. IEEE Toronto Section Milestone committee comprised of: Pat Finnigan (SMIEE), Inci McGreal, Ron Potts (Region 7 LM Coordinator), and Bert deKat (IEEE Hamilton Section). “We had a tremendous amount of help and support from IEEE Region 7 staff, and also the staff at the IEEE History Center, as well as the evaluation committee, comprised of very senior, experienced, and supportive reviewers” says Pat Finnigan, who led the Milestone to successful conclusion.
On April 24, 2007, IEEE Toronto Section made its final submission for the IEEE Milestone. The submission was approved June 30.

8.0 References:
[1] CBC Digital Archives, Broadcast on May 19, 1984, http://archives.cbc.ca/on_this_day/10/08/

[2] Tom Kenny, The Nuts and Bolts of Cardiac Pacing, Chapter 1

[3] Seymour Furman, MD, Early History of Cardiac Pacing and

Defibrillation, Indian Pacing Electrophysiology Journal, 2002 Jan–Mar; 2(1): 2–3.

[4] Maulik V Baxi, First Artificial Pacemaker, A Milestone in History of Cardiac electrostimulation, http://www.asmj.netfirms.com/article0903.html

[5] Heart Rhythm Society, http://www.hrsonline.org/News/ep-history/topics-in-depth/hymanspacemaker2.cfm#Problems

[6] Showcase of Canadian Engineering Achievement, IEEE Canada web site, http://www.ieee.ca/millennium/pacemaker/pacemaker_about.html

[7] Jo Ann LeQuang, Pacemaker, Implantable Heart Technology Turns 50, http://www.articlesbase.com/health-articles/ happy-birthday-pacemaker-implantable-heart-technology-turns-50-495628.html

About the Author

Visda Vokhshoori is currently, a developer of the optimizing back end of the IBM XL compiler brand, Visda has been in IT for more than 10 years. She has spent her career since graduation from the EE Department of State University of New York, New Paltz, at 4 different groups, in 2 different countries with IBM. With each change, she has set the bar higher for herself, working on more complex set of computing problems. She obtained her MSEE from Columbia University, New York, in 2002.