A Shocking Experience with Respiratory Arrest

Reborn at age 24.

By Max E. Valentinuzzi

"No one can confidently say that he will still be living tomorrow," wrote Euripides in his play Alcestis *(438 BCE). But I recall a day when, surprisingly, I returned from the shadows and the next day, even though a little shattered, was still alive.*

It was 23 March 1956. I got up very early to arrive on time, 7:45 a.m., at the Montegrande transmitting station of Transradio International, then a leading point-to-point private communications company that was part of New York-based RCA Communications. The plant was located beside the freeway near Ezeiza Airport of Buenos Aires City in Argentina. A young and energetic telecommunications engineering student at the University of Buenos Aires, just turned 24 and immersed in finishing a few final courses, I worked as a technician at the Montegrande station, which was full of secrets I discovered daily with astonishment and delight. (I also played piano in a small band to save money, for I was about to be married.)

The plant had 36 power amplifiers along with the equipment to handle telegraphy (Morse code was still in use) by on–off or frequency shift keying (FSK) as well as telephony (although not so much the latter); in addition, teleprinters were slowly but steadily being introduced based on time multiplex systems [1]. The station occupied an estate of several acres, dotted with antennas and a well-kept network of aerial two-wire lines (Figure 1), and generated a huge high-frequency electromagnetic field, occasionally disorienting messenger pigeons and other birds. A maintenance patrol often had to repair these lines after strong winds or storms. Situated on a low lying field, the estate easily accumulated water during rains and so was, by and large, rather muddy, which ensured good ground connection and made it an excellent location for the system. The plant and surrounding estate made an impressive appearance, and we were proud to work there, as the site acted as a port from which an enormous amount of information, mainly commercial, flowed out to the world [2].

With FSK, which is still used as a method for transmitting digital signals, the two binary states, logic 0 (low) and 1 (high), are represented by an analog waveform: logic 0 by a wave at a specific frequency, and logic 1 by a wave at a different frequency. A modem converts the binary data from a computer to FSK for transmission over telephone lines, cables, optical fiber, or wireless media; it also converts incoming FSK signals to digital low and high states, which the computer can "understand." In addition, the station used double-FSK or TWS (for *twin system*), which worked with four frequencies and carried two information channels. This is the simplest system of a family now called *M-ary transmission*.

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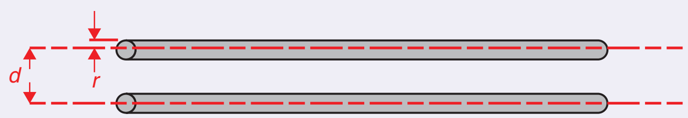
The station supervisor, Mr. Héctor Peña, had assigned me what I considered a challenging project: to complete and adjust the final stages of a 27-MHz, 3-kW output amplifier intended to be used for telegraphy with any of these modulating systems. Its supply voltage was 2,400 Vdc. Similar pieces of equipment were fed with voltages as high as 10,000 V. Work on the two-stage equipment assigned to me had been started



$$Z_0 = \frac{276}{\sqrt{k}} \log \frac{d}{r}$$

Z_0 = Characteristic Impedance of Line
d = Distance Between Conductor Centers
r = Conductor Radius
k = Relative Permittivity of Insulation Between Conductors

FIGURE 1 The characteristic impedance Z_0 of a parallel two-wire line. It is very important to keep the distance between both wires constant; otherwise, a mismatch would occur, along with energy loss. The Z_0 of a circuit, when connected to the output terminals of a uniform transmission line of arbitrary length, causes the line to appear infinitely long. If the uniform line ends in its characteristic impedance, there are no standing waves, no reflections, and a constant ratio of voltage to current at a given frequency at every point on the line.

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but left unfinished by someone else several months before; it was installed in one of the racks within a long line holding other amplifiers of different frequencies and nominal powers. I had been working on it for several days, checking, fixing, and changing parts, and was already running preliminary tests.

Because the frequency provided by a suitable oscillator was rather high (27 MHz), the final primary coil had few turns—about six, divided into two sections air-coupled to a central, secondary coil that began the outgoing line to the antenna. The primary coils were furnished with adjustable clamps or braces, so a user could select even a fraction of a turn. As in other high-voltage equipment, a safety hook bar connected to the rack allowed the user to touch the primary coil (the coil coming directly from the plates of the two push–pull high-vacuum output tubes) and ensure that the current was turned off. Connection to the 2.4-kV current was made indirectly via a relay, another safety feature.

That day, I was adjusting the primary coil by moving one of the clamps to optimize coupling, connecting the power supply, checking the signal on the oscilloscope, turning it off, and attaching the safety hook to the primary coil to be sure no tension was still there. I had performed this task sequence several times, always assisted by another young technician named Rivas. In the course of this series of on-and-off trials, something must have come out of place (the safety hook, perhaps?) or, alternately, become stuck (the mechanical relay part, maybe, or the actual switch?). Or (worse than these possibilities) did I make a mistake or forget something?

At any rate, in the middle of one of the tests, I placed my left hand over the primary coil to loosen the clamp so I could shift its position. I attached the safety stick to the coil and saw no indication of a short circuit. But the high voltage was still on, and my hand was caught for a short while, closing the circuit, with my bare right arm (I was wearing short sleeves) touching the other side of the rack. My partner Rivas pushed me hard to free me from the trap (remember this was dc, which tends to hold the victim as if glued), and I fell to the floor, literally flying over a short wooden ladder behind me. In fact, Rivas briefly felt the discharge too, as he later told me. I recall the intensely painful trembling current traversing my body diagonally from my left hand to my right elbow and feeling Rivas' push; then I blacked out.

The emergency personnel were quite efficient and knew what to do. They checked my heartbeat. Still there. But I was not breathing, so they started artificial respiration—for 45 minutes! Someone told me later that I was becoming cyanotic, and they feared I was about to leave them. At one point, I opened my eyes, saw them all around me—in particular, one fellow sitting on my belly pushing my chest—but I could not breathe and realized I was going to die soon. It is difficult to say whether this awakening lasted a minute or more. For me, it was an eternity. Suddenly, a strong muscle contraction made me inspire deeply, and again, and again. There were shouts and laughter as excited silhouettes moved all around me. Everything was over, or at least the most difficult stretch. I was carried to a small emergency room for a quick checkup. My father was located, and he came to pick me up. My mother declared I had to quit the company and search for a safer job.

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Over the next few months, I underwent treatment for my nasty-looking hand and arm burns and had a series of medical checkups, plus the rest I needed to heal during the long recovery process—time I used preparing for the examinations I required to graduate, which I did a little more than three months later on July 10. The worst part of my recovery was the loss of sleep; I had awful nightmares and often woke up reliving the sensation of the electric shock.

I returned to the company in September. Mr. Peña told me later that everything had been checked and appeared fine; hence, the conclusion was that it had been a human mistake. In other words, I was held responsible, which meant the company had no liability. I was transferred and promoted to engineer in the central laboratory, located in downtown Buenos Aires. And so began a new, productive, and happy stage in my professional career.

The coil turn I touched with my left index finger that day and the clamp I touched with my hand left scars that are still clearly visible even now, after 60 years: the current destroyed the tissue on its way in. My right arm bears a mark, too, even though it required less time to heal than the finger burns; an outflow current is less destructive.

Fortunately, my heart did not fibrillate—neither the atria nor the ventricles. Because it was a dc discharge, the connection of the established circuit (from my left hand to right elbow), which certainly provided a nice path across the heart, could have triggered an arrhythmia only if the current had passed through my heart during its vulnerable period [3]: this period, in electrocardiograph terms, is the portion of the electrocardiograph (say, the T-wave) during which the ventricles are most sensitive to any disturbance, and, therefore, their probability of fibrillation may be high [4]. Could I have known that, years later, fibrillation and defibrillation would become one of my research interests? Call it a coincidence of life, or some mysterious karma, or the designs of the Great Engineer, or just pure chance…whichever you like best.

The moral of the story is this: respect electricity, even if you are familiar with it because it is your métier. Respect it even more if you are handling high voltages. Do not hurry. Think twice before any movement. Know well where you are standing, and put one hand in your pocket if possible while touching the hot wire with the other.

One final comment: ac electricity is more dangerous than dc, if you think in terms of cardiac fibrillation; in a situation such as I experienced, a train of 50- or 60-Hz pulses would traverse

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where these basic concepts apply to nonmedical applications and correctly solve the exam problems. This is borne out by the fact that, while only a small number of biomedical engineering graduates take the PE exam, many of those who do, pass successfully.

Looking Ahead

As we prepare our biomedical engineering students for professional practice, we should encourage them to become licensed. Licensure provides many benefits to engineers, employers, and the general public and can only enhance one's career. If we are providing our students with a solid foundation in engineering fundamentals, then they should able to pass existing FE and PE exams. As medical devices become more complex, the potential for more product recalls increases. If patient outcomes are adversely affected by product failures, then medical consumers and state regulators could demand a repeal of the industrial exemption to better protect the public. If licensed, our students will be prepared for these potential changes.

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RETROSPECTROSCOPE *(continued from page 41)*

one's heart, no doubt catching the vulnerable period. Marconi was right after all in saying, when he argued against Westinghouse's stand in its struggle to impose one type of current over the other (and forgetting transmission efficiency), that ac is more dangerous; he even ran experiments on dogs, for that matter. But that is another well-known story.

Postscript: Because I was reborn at age 24, that means I am 24 years younger now. Despite the pain I went through, the deal turned out to be advantageous!

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