IMPEDANCE MATCHING

H.T. HALL 03-14-95

When I was young, baseball was my favorite game. It was also my father's. He was the catcher for the "Ogden White Sox" of Ogden, Utah, a minor team in the northern Utah--Southern Idaho area.

I mentioned baseball in a prior story entitled "school Bullies". I was good at baseball and hit more than my share of home runs in playing with the other boys. But I was ridiculed by them for always using a light-weight bat that the girls used in playing soft-ball (we boys played hard-ball).

We had a good selection of bats for playing hard-ball and the other boys, who were heavier, taller and more muscular than I would always pick out a very heavy bat. Their reasoning: "a heavy bat will knock the ball farther, dummy, that's obvious."

I did not argue with them over the matter of light bats versus heavy bats. I had experimented with using the whole range of bats, and their weights and by trial and error discovered the particular bat best for me. If I was a "sissy" for using a certain "girls" bat--so be it. I didn't care.

At that time in my life at the Marriott School, the physics to understand why my trial and error selection of a bat was correct did not exist. In fact, I did not learn the necessary concepts until I had spent two years as a World War II Navy Ensign in the extensive study of electronics and radar at a number of schools. They included Bowdoin College in Brunswick, Maine, MIT in Boston, Massachusetts, Harvard in Cambridge, Massachusetts, and study at an advanced Navy Radar Training School in Honolulu, Hawaii. With that introduction, we'll return to baseball and other matters later.

There I was, laying flat on my back on the deck of the Battleship Missouri, looking at the sky and eating a banana. The deck was awash with sailors and other servicemen who were returning home from the Pacific conflict now that the war was over. Ordinarily, as an officer, I would have had a bunk to sleep in but every nook and cranny of that ship had a body in it. I was every man for himself. As the ship rolled slowly from side to side, I mused about the relaxed assignment I expected to have at Pacific Fleet Headquarters command at San Francisco Bay.

I was to be officer in charge of electron tube storage! Up t now, I had nothing but study, study, and study. Not that I didn't really like to study, but a body does need an occasional change of pace. The standard pattern that I had been following for the better part of two years was this:

<u>Monday Through Friday</u>

8:00 A.M. to 12:00 Noon four sessions of lecture by four different teachers with 5 minute breaks on the hour.

12:00 to 1:00 P.M. study while eating lunch.

01: to 5:00 P.M.laboratory Studies &experiments

Evening: Get your dinner and study until 10:00 P.M. or beyond in preparation for next morning's class

Saturday: 8:00 A.M. to 12:00 Noon. A four-hour examination

12:00 Noon free unless you need to study for next Monday

Sunday: Go to church if an LDS facility is available.

As I was finishing my banana, a message came over the ship's horn:" Is there a radar officer aboard? If so, report to the bridge."

I answered the call and found my way to the bridge and the commanding officer. He informed me that his radar was not working and that he did not wish to go into San Francisco harbor without his radar (at this time, we were about a hundred miles from shore). I was taken to the radar room and immediately set about to ascertain the problem. Incidentally, radar technology was a most important World Ward II secret and all radar officers and technicians had to have government secret clearance. At school, while in training, we had to clear armed guard security posts to enter radar technology areas.

At the ships radar room, I was confronted with the usual array of electronic components: a sea of twin triode 6SN7 electron tubes. Their combined heating elements alone, consumed 15 kilowatts of electricity. Then there were the Klystrons that generated the centimeter wavelength electromagnetic waves that sent out the pulse of energy that would bounce back as an echo to the ship's antenna from objects that were in the air on the sea. Also there were the very large Eimac quadruple element, triode power tubes (manufactured in Salt Lake City) whose rare tantalum plates, operating at four thousand volts, glowed white hot as if they were an arc lamp.

Then, of course, there was the usual array of electronic elements such as cathode ray tubes, meters, relays, timers capacitors, inductors, transformers, resistors, wave guides, coaxial cables, and, of course impedance matching networks.

After several hours of checking, with one hand behind my back, a safety measure deeply ingrained in us in our training. Very often, we might be adjusting a 4,000 volt "trimmer" with a screw driver just one inch away from the lethal voltage.

At last, I found a defective relay in the system. Spare parts aboard ship are carried in a number of steel trunks, but a replacement relay could not be found. Consequently, I had to improvise a repair on the bad relay itself. The repair worked and our ship was able to come into port with it's radar working.

Interestingly, my schooling in electronics must have cost the U.S. Navy many thousands of dollars. Fixing the relay was the only constructive thing, relating to my training, that I ever did

for them. However, I suppose that "being trained and available", does have a compensating monetary value.

In another story, I hope to tell you how I managed to get into the Navy's Radar program, but for now we need to get on with "Impedance Matching."

I'm going to get a bit technical for a while but stay with it. It will widen your horizons. I will talk about energy and work. The dimensional units of energy and work are identical: millimeters squared divided by time squared. Energy may also be defined as the capacity for producing effects, said effects being of widely different character. Energy may be classified as being stored or in transition. Examples of stored energy (1) mechanical, as in a flywheel, where the stored energy in the revolving wheel is given by the formula: Energy equals one half times the velocity (speed of rotation) squared. (2) Another type of stored mechanical energy can be found in a spring or (3) in a rock that could fall off a roof. (4) energy can also be stored as heat by insulating a hot object. (5) In electricity, a condenser containing a charge of electrons would constitute an example of stored electrical energy.

After engaging in some light banter with Dean Barnett last week, I've decided to take a more serious look at the business of repairing the faulty relay. He said that fixing the relay was probably the most important thing that I had done in my life. I'm quite sure that he said it in jest, but on reflection, he may be right. The battleship was probably worth a few billion dollars. Additionally, there were more than ten thousand souls aboard, who had survived the Pacific conflict. How awful it would be if this enormously overcrowded vessel would collide with another at this time.

A ship without radar is a ship with impaired vision. Who knows what may have happened if the ship had gone into port without its radar working?

Well, back to the chart that I promised. At the bottom of the page, several types of energy, together with their extensive and intensive factors are listed. The product of these factors are listed. The product of these two quantities is equivalent to the energy which is commonly measured in the units indicated.

Wherever I turn in the scientific world, I see parallels to gospel principles. There are so many things that have a dual nature, or conjugate relationship: Man & Woman, the celebrated Particle & Wave nature of light, The Father & the son, the Body & the spirit, the good and the bad,the Positive & Negative (electricity), the North & South magnetic poles, and so it goes. Somehow, I feel these relationships to be fundamental principles from a former sphere whispering to me of the truthfulness of the Latter-day Gospel of Jesus Christ. Just for myself, in this present discussion concerning energy, I see the spirit as the intensive factor and the body as the extensive or capacity factor. In science, as well as in the gospel, the intensive factor is responsible for promoting changes.

We often use the phrase, "being in tune", usually with the Spirit, our Heavenly Father, or

with our Savior. Sometimes we say, We are on the same wave length, of have the same vibes. This comes from the early days of radio and is a very good analogy. If we are in tune, we can be empowered under certain conditions.

This is where I finally introduce you to Impedance Matching.I have an impedance matching device descending from the TV antenna on top of my house. Mine is of the twin lead type where two copper wires are embedded in a plastic ribbon about one-half inch apart. Stamped at intervals along the ribbon are the words, impedance 300 ohms.

Physical Science, requires mathematics to empower its usefulness. In the field of electricity and magnetism of which World War II radar was a practical branch, "Functions of a Complex Variable," or so-called "Imaginary Numbers" are important.

I previously told you that the intensive factor is responsible for promoting changes. I also likened our spirits to the intensive factor of energy. Given the opportunity, our bodies should respond to the promptings of the inborn goodness of our spirit to make righteous changes in our behavior.

Carl Frederich Gauss, the eighteenth century scientific genius and "Prince of Mathematics" incorporated the square root of minus one (an imaginary number designated as (i) into a framework to deal with practical electromagnetism at high frequencies. Simplistically, impedance takes the mathematical form $Z=(a+ib)$, the starting point for mathematical elaboration. You don't need to remember that, only remember that Z stands for impedance.

Z is important for the transmission of power. The mathematics developed for electronics has exact counterparts in other areas, particularly in mechanical systems.

In and automobile, the necessity of matching the energy available at the power source (the engine) to the sink (the wheels) is manifest by the gear shift box or automatic transmission. Have you ever tried to begin forward motion of your automobile in high gear? It doesn't work, does it?

Gears, levers, pulleys, coaxial cables, and parallel 300 ohm twin lead TV wires all serve the same purpose- the effective transfer of energy from source to sink by impedance matching.

Think of it! Our source of power is our Heavenly Father, through His Son, Jesus Christ. If $Z_{ME}=Z_{HF}$ where Z_{ME} stands for my impedance and Z_{HF} represents the impedance of our Heavenly Father, unimpeded power could flow from Him to me. Of course, this could not happen unless I had Heavenly Father's perfection. It follows, however, that everyone on this earth should strive for this ideal.

Well, this is getting quite metaphysical, so just regard this discussion as some thoughts floating through my brain.

Take a look, again, at the Energy Chart. Under "Type of Energy", find "Kinetic". The extensive factor is the mass (weight of an object). The intensive factor is velocity (speed of travel). Note that the intensive factor is velocity (speed of travel). Note that the intensity of

the velocity factor increases with its square (a velocity of 10 miles per hour becomes 100 miles per hour). Note that the one half factor decreases the intensity to only 50 miles per hour but a five fold increase is certainly a lot.

Now we take this to baseball where this story began. The mass of the baseball is a fixed quantity (invariant). That, I can not change. But I can certainly control the velocity with which I swing the bat within the limits of my physique, and I can swing a lightweight b at with a higher velocity than a heavy one. A heavy bat swung slowly could contain less energy than a light, fast swinging bat because energy increases with the square of the velocity but only linearly with the weight of the bat. Here, we have to deal with a complex situation, *impedance matching* , if you will. I have to match the energy (available at the source (myself) to the sink (the ball).

It has only been since world war II that professional base ball players began to investigate this situation in detail. They too, like my muscular classmates at the Marriott school, considered a heavy bat to be the best.

I will always remember that boy of long ago, standing at the plate, waiting for the pitch, ready to swat the ball out of the field with a girl's soft ball bat!