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AUTHOR

Milton Lewis

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THE ROLES OF SCIENTISTS AND ENGINEERS IN DEVELOPING A NEW PROCESS AT THE HANFORD LABORATORIES

By

Milton Lewis

You men are standing at an important crossroads. You are trying to decide on a career. For each of you it is one of the most important decisions you will ever make. Interestingly enough, it bears a strong similarity to another equally important decision that most of you will also make.

Some day in the not-too-distant future you will choose a wife. In both cases your decision will be with you for the rest of your life. If you choose wisely, your choice can be a joy forever. If you make a poor choice, you may face a life of misery. In both decisions there is an element of chance. For the most part, though, you are in control. You have a better chance of making a wise decision in both cases if you will decide carefully and on the basis of as many facts as you can get.

I would like to help you make your career decision. Most adults would like to help you. All we can do, though, is to tell you of our experiences and our thoughts. The choice is up to you. Get as many facts as you can. Ask as many questions of as many people as you can. Put them all together, factor in your own abilities, goals and aspirations, and then make your decision. During your college years, keep up your inquiries and continually re-evaluate your decision. Remember that there is no disgrace if you change your mind, and modify your career plans. However, don't vascillate. Set a course, and follow it. Change it only for good reason and after much deliberate thought.

If a boy wants to become a doctor or a lawyer or to go into a business or a craft, he doesn't have much trouble finding out what his work will be. He can observe doctors and lawyers at work. If nothing more, he can watch TV. He sees businessmen every day and has plenty of opportunity to watch craftsmen. Unfortunately, he has very little opportunity to observe a scientist or engineer at work. Even many adults do not know what a chemist or a physicist or a mathematician does. They have only a hazy concept of the work of a mechanical engineer, electrical engineer, or chemical engineer. This lack of knowledge has two distinct and opposite effects. For those young men who like to try new things, it draws them like a magnet - and because some of them will not be properly informed, they may be disappointed. For others who are more cautious or, who lack confidence, it frightens them off - and yet for some of them science or engineering might be just their "meat".

I urge you, therefore, to seek information and to decide only after you have a lot of information. Tonight I'll try to give you a little. Mainly, I hope to interest you in asking questions and getting more facts.

Because the field I have to cover is so large, I will use an example. At Hanford we are developing methods for peaceful uses of plutonium. In one program we are doing research and development on the utilization of plutonium to fuel nuclear power reactors. This program uses at least one of almost every kind of scientist and engineer you can think of. I'll have to back down a little - I don't know of any astronomers on our staff - but then, I don't know everyone working on the program either.

As my example, I am going to discuss with you the things that go into the design and final use of this plutonium fuel element. As you know, one doesn't travel around with a plutonium fuel element in his pocket, so I'll admit that this is only a model, but it will serve our purpose.

To go back to the beginning, let's start at the point where plutonium was discovered in 1940. A physicist, Edwin McMillan, was experimenting with uranium to measure the energy of its fission fragments. In making his measurements, he noticed the presence of another product - a radioactive substance with a half-life of 2.3 days. Since there was no evidence of energy release, he concluded that it was not a fission fragment. He theorized that it was a new element, number 93, produced by the capture of a neutron by uranium-238 and prompt radioactive decay. Later, he and another physicist, Philip Abelson, confirmed this and named the new element neptunium. They suspected that neptunium decayed to a 94th element but their assignments to other war work prevented them from proving it. A chemist, Glenn Seaborg, who knew of their work, asked their permission to continue it in an effort to find and identify element 94. This he did and named it plutonium. Not long after its discovery, plutonium was found to be fissionable, like U-235. This discovery opened the door to the use of plutonium for a bomb and eventually to produce power.

Between 1941 and 1956, fifteen years, hundreds of scientists measured the properties of plutonium. Physicists measured its ability to capture neutrons and to fission; others measured the energy of its fissioning; some measured its critical mass and others its isotopic composition. Chemists made it into various chemical compounds with fluorine, chlorine, oxygen, etc. They measured the rates of its reactions with other substances; some measured its solubility in various solvents. Some analyzed the fission products and identified them. Others measured its emission spectra and its absorption spectra. Mathematicians calculated its thermodynamic properties from the spectral data. Biologists studied its effects on living things and plants. Metallurgists made alloys with other metals and measured their strengths.

I don't mean to imply that all this was done at Hanford, although a good deal of it was. Research was going on at many Atomic Energy Commission laboratories and at some university laboratories. In the story of plutonium, this was a period of data gathering, a period of learning. To a large extent this is in the field of the scientists: to study the behavior of matter, to learn as much about it as they can, and to report their findings for the human race to do with as it wishes. Even if no one suspected that plutonium could be used to produce power, scientists would measure its properties - just for the sake of knowing them.

The engineers were busy too. They were using the scientists' data to figure out uses for this new plutonium. Mechanical engineers were designing nuclear reactors that would allow plutonium to be fissioned under control and to remove the heat and use it. Electrical engineers were designing and testing devices to measure the radiation or to turn the heat into electricity. Chemical engineers were figuring out how to purify plutonium and how to put it in the forms that were needed in reactors. Metallurgical engineers were inventing and testing methods to fabricate plutonium into alloys and shapes like this fuel element and developing materials to coat and protect the plutonium alloys from corrosion by cooling fluids. Just as with the scientists, knowledge and information were their goals, except that perhaps you noticed in my words that the engineers quest for knowledge was directed towards an end product useful to man; whereas, the scientist was not necessarily interested in the final application of his knowledge.

Six years ago the Atomic Energy Commission and the General Electric Company at Hanford agreed to develop methods for utilizing plutonium in nuclear power reactors, that is, to make electricity. This decision was made by scientists and engineers also, but these scientists and engineers were administrators. Their function was, and is, to use their scientific and technical knowledge to plan and guide the research and development work at Hanford. Their decision was based on the knowledge of plutonium that was available at that time, on their knowledge about the capabilities of the scientists and engineers at Hanford, and their knowledge about the needs of the country for nuclear fuels. As managers of research and development work, their training as physicists, chemists, mathematicians, mechanical or electrical engineers is very important. However, they must also be skilled in finance, business methods, personnel management, planning, public relations and all the many other activities of a large technological business enterprise.

In cooperation with the scientists and engineers on their staffs, the managers decided to build a reactor for testing plutonium fuel elements. A few preliminary decisions were made about the general type of reactor to build and its approximate power output. These decisions were based on the need for testing large numbers of fuel elements to get reliable data, on the need for large-scale physics data, and last but not least, on the amount of money available. Then they authorized the engineers to begin design of the reactor and the fuel elements. They also directed the physicists to calculate the amount of plutonium and uranium needed and how it should be distributed to allow the reactor to go critical. The chemical engineers began to design processes to dissolve the fuel elements after irradiation so they could recover and purify the plutonium. All in all, about 175 technical people applied their various and varied skills to put in motion this large program.

Let's look at one specific part of it more closely. Let's follow the design and fabrication of this fuel element. From previous experience, mechanical engineers who are heat transfer experts calculated the surface area required to remove the heat that would be generated and lower the temperatures that would be reached. Physicists calculated the plutonium concentration required and the limits on the amounts of other materials that could be present so as not to lose too many neutrons. Between them they evolved the general size and shape of the proposed fuel element. It was agreed that the right surface to volume ratio and spacing could be achieved through the use of this cluster of rods. Then they called in the metallurgical and chemical engineers. The former agreed on an aluminum alloy material for the core of the rods where the plutonium would be and started work on the method of making it. The latter from their corrosion experience chose materials for the outside or cladding to protect the core and contain the fission products. They suggested aluminum, stainless steel, or zirconium. The mechanical engineers rejected aluminum because it would not be sufficiently corrosion resistant. The physicists rejected steel because it absorbs too many neutrons. Zirconium, a relatively new metal with many unknown fabrication problems, was finally agreed on. Metallurgists went to work to develop methods for fabricating, welding and testing zirconium. Design engineers proposed methods of assembling the rods and spacing them and holding them in place. Finally, by mutual agreement among the many people involved, this 19-rod cluster element evolved and the design was frozen. It was now up to the metallurgists and metallurgical engineers to make it. They tried about three different kinds of casting. They tried extruding the alloy like toothpaste from a tube.

They tried swaging - a hammering process - both hot and cold. Samples by each method were made and tested. Gradually the best method for each step was decided upon. A flowsheet was layed out showing the entire process and how each step would be carried out. Equipment to do the jobs was designed and ordered from companies who specialize in making such equipment. In fact, a whole production plant, on a small scale, was built to produce fuel elements. Basically, the process used was to melt plutonium and aluminum in the right proportions for the core material. This alloy was extruded into one-half inch diameter by eight feet long rods. The rods were placed inside long zirconium tubes and swaged, or hammered to the exact final size. The ends were welded closed with heliarc welders and tested for leaks. Zirconium wire separators and hangers were attached and the entire assembly tested by putting it in a steam pressure vessel for several hours. If no radioactive contamination was found in the steam, the element was considered ready to be irradiated. Eighty-five fuel elements of this type were loaded into the reactor. Physicists measured the nuclear properties of this array of fuel elements. When all was declared ready, the cooling water was started to flow, the moderator level was raised, and the Plutonium Recycle Test Reactor went critical.

I am pleased to say that the original 85 fuel elements and many others that replaced them as they finished their jobs performed fully as expected in the reactor for its first two years. In the meantime, new and better designs were developed and the new fuel elements fabricated, this time with a ceramic core. The ceramic fuel elements are now in the reactor, replacing the alloy type, and they are being tested. Even better designs are already being worked on as we learn more each day. The cycle will continue until a practical and safe fuel element has been tested and can be recommended for industry to make and use in commercial power reactors.

I have been necessarily sketchy about some of the details because of time limitations. For example, I haven't described the important role of the mathematicians in helping to design the experiments so that they are statistically sound, and in evaluating the test data to draw sound conclusions. As you can tell, however, the overall program requires the talents of many kinds of people with many kinds of technical training at all levels. Each must know his specialty well, and yet, each must understand how his specialty fits the entire program. Thus, each man's training must include at least an understanding of the others. The physicist must know some chemistry and lots of math. The mechanical engineer must know his scientific principals as well as his engineering. It means a lot of hard work, but I can tell you it is well worth the effort. Give it your serious consideration.

(Slides illustrating steps in the talk will be included as appropriate).

M. Lewis:lg
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