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ADMIRAL H.G. RICKOVER'S IMPACT ON NUCLEAR POWER

Theodore Rockwell

Admiral Rickover was responsible for the development, construction, operation, repair, refueling, and maintenance of more power reactors than the total of all other American power reactors. In addition, he was responsible for Shippingport, the world's first commercial atomic power plant. Almost none of the necessary technology was available; it all had to be created by his program. This included development of fuel materials and construction materials such as zirconium and zircaloy, beryllium, reactor grade uranium oxide, hafnium, and stainless steels. It also involved radiochemistry of liquid metals and of high-temperature water, reactor physics, radiation protection and safety, heat transfer, fluid flow and a wide range of basic component and system development. These subjects were all classified in the early 1950s, and Admiral Rickover had his people prepare a meticulous, detailed series of technical handbooks and then had them all declassified and widely disseminated. Everything associated with Shippingport was unclassified from the start.

In addition to the handbooks, the Naval Reactors program developed scores of codes, standards, criteria and procedures that formed the foundation for the international nuclear power industry which followed. The program also trained over 10,000 officers and 60,000 enlisted personnel, and set up facilities for designing, constructing, maintaining and repairing nuclear plants, which set the pattern for the industry. There is a crucial difference between ideas and accomplishments, the difference that distinguishes science from engineering. The understanding of natural phenomena developed by science enables engineers to envision and create concrete realities. It was as an engineer that Rickover was uniquely effective. The entire nuclear power industry continues to display his contributions.

To most people, Admiral Rickover means nuclear submarines. On second thought, some people will recall that he also built a few surface ships. You may not all realize that the number of naval nuclear power plants has at all times exceeded the total number of all nuclear power plants operated in the U.S. by all other operators. And there were a great many significantly different types of reactors in this group. Rickover and his people managed the development, construction, operation, repair, refueling, and maintenance of this mighty fleet. In addition, I would hope that most of you in this room would then think to mention the Shippingport Atomic Power Station, the world's first commercial atomic power plant. Here, for the first time in history, was a living, working model of how to build, operate and support a commercial nuclear power station. A truly impressive and important legacy of the Rickover program to the whole world.

However, Admiral Rickover often said to me, as I'm sure he did to many of you, that if all the hardware we worked so hard to create were suddenly to disappear, leaving behind only the impact of the program on the people, then he would still consider his efforts worthwhile, because he felt that the changes brought about by the program—changes in people's thinking and practices—were more important than any of the hardware. And today, with the hardware of Shippingport decommissioned, and many of the submarines being decommissioned in accordance with disarmament agreements, we can evaluate and appreciate the wisdom of that point of view.

Let's briefly review some of the Rickover contributions to commercial atomic power. Admiral Rickover did not invent or discover nuclear power, but more than any other individual he made it a reality. Americans are quick to give credit to a person who comes up with a new idea, but we are less apt to recognize the importance of the difficult process of implementing an idea, of making it a reality in the world. There is a crucial difference between *ideas* and *accomplishments*, the difference that distinguishes *science* from *engineering*. The understanding of natural phenomena developed by science enables engineers to envision and create concrete realities. It was as an engineer that Rickover was uniquely effective.

So, what is the Rickover legacy? First, of course, there is the lasting benefit from all the technology it took to create and support Shippingport and the naval reactors. That includes a great deal of development work on fuel materials and construction materials such as zirconium and zircaloy, beryllium, reactor grade uranium oxide, hafnium, and stainless steels. It also involved radiochemistry of liquid metals and of high-temperature water, reactor physics, radiation protection and safety, heat transfer, fluid flow and a wide range of basic component and system development. Not content to let this technology spread by word of mouth, Admiral Rickover insisted we describe it in meticulous, professional detail in a series of about a dozen Naval Reactors handbooks. As those of you know who have written a book, or even a serious technical paper, the process of organizing, writing and documenting a new area of research and technology, and submitting it to peer review, can be as much a creative process as the original work, and results in more than a mere snapshot of something already in existence. Some of the Naval Reactors handbooks have been used for nearly 40 years as textbooks, training manuals, or source books in civilian installations all over the world, and are still being cited in the scientific literature.

We sometimes forget that in the early 1950s, nearly all nuclear reactor work was classified, and it took long and continued negotiation between the Admiral and Jim Beckerley, then Director of Classification for the AEC, to permit these new areas of science and technology to be made available to the world. I remember the widespread shock and surprise when Rickover announced that he wanted *no* facilities at Shippingport for storing or handling classified material. And when he stood in front of the newsreel cameras at the height of the Cold War, with Frol Koslov of the Soviet Union, and told him that he could take his camera through the plant—that there were no secrets there—he was announcing publicly that he intended this technology to benefit all mankind.

So I consider the Naval Reactors Handbook Series a symbol of Rickover's contributions to the commercial industry. But this was just the beginning. For example, many of the codes and standards now used as basis for the civilian nuclear power industry were first developed for naval reactors. The Boiler and Pressure Vessel Codes, several important welding standards, and of course a large number of the ANSI standards can trace their ancestry directly to that early work. Many of you have served on standards committees,

and you know how much of a contribution this represents.
There are other forms of standards, models and paradigms which owe their origins to Naval Reactors. I remember long talks with the late Rogers McCullough, then head of the Advisory Committee on Reactor Safeguards, on the question: how do you go about formally evaluating the risks associated with bringing an operating nuclear power plant into a busy port? Sid Krasik, the widely respected Bettis physicist now also deceased, injected a great deal of wisdom and insight into these discussions. We finally decided to take it in four separate stages: initial criticality, low power operation, initial sea trials, and refueling, and we agreed on what each of these stages would encompass.

The presentations were prepared, polished and rehearsed. At the first meeting, covering only initial criticality and no power operation, Ed Teller opened the proceedings by noting that the last time he had been in the New London area was right after a hurricane, and his train was delayed because a small boat was lying upside down across the railroad tracks. "What if that had been the *Nautilus* ?," he asked ingenuously. That, of course, got the meeting off on a somewhat different track than we had planned! But we were able to show that neither that question, nor many others they threw at us, created any public hazard. Through several years of working with the ACRS, before the days of the NRC, we helped establish criteria and procedures for considering and evaluating the safety aspects of operating, supporting and maintaining power reactors that were largely applicable to civilian plants.

Another clearly definable Rickover contribution was the establishment of a nationwide system of training programs, schools, curricula, texts, and instructors, covering basics such as math, nuclear physics, radiochemistry, heat transfer and fluid flow, materials and metallurgy, and more specific topics such as reactor plant dynamics and control, health physics and prototype training and qualification. These training materials became the basis for the civilian programs that followed, and over 10,000 nuclear-trained officers and nearly 60,000 enlisted men provided a priceless source of experienced personnel for the new civilian industry.

The fact that Rickover's military technology was so directly useful for civilian installations reveals a great deal about the philosophy that he applied to the whole Naval Reactors program. Where military requirements were more stringent than commercial requirements, he insisted we meet the more rigorous military ones. For example, the land-locked *Nautilus* prototype plant was completely fitted into the submarine hull, although it would have been easy to argue that such problems could be faced later. And the military need for ruggedness and shock-resistance were not compromised. I remember when Rickover showed slow-motion movies of laboratory shock tests and depth-charging tests on submarine equipment to the scientists at the Oak Ridge National Laboratory. They blanched as pieces of electrical switchgear broke off and drifted lazily through the electrical panels, shearing and shorting out other equipment as it went.

As a result of facing this requirement for ruggedness from the very beginning, we were able to take the laboratory glassware, rubber tubing and gas handling systems, which characterized the early low-level BF3 neutron detectors, and develop them into "pieces of pipe," which Rickover delighted in hurling into radiators to demonstrate their ruggedness. Such detectors and their associated electromechanical systems, though designed to military standards, were a vital part of the laboratory-to-power-plant development that made nuclear power a commercial reality, as well as a military reality. Similar miracles were required to create industrial facilities and processes capable of manufacturing huge, highquality pressure vessels, pumps, valves, heat exchangers, control rod mechanisms and fuel assemblies.

But where military necessity might have permitted easier standards, Rickover again chose the hard road. Take radiation standards, for example. At the Admiral's request, I had long talks with KZ Morgan, then at ORNL, on the Admiral's philosophy for permissible radiation levels. Dr. Morgan thought we were being unnecessarily restrictive by applying civilian standards to military vehicles. He told me the nuclear airplane project was counting on using up to 25 Rem per flight and 200 Rem per tour of duty, and Rickover's use of the civilian limit of 5 Rem per YEAR seemed to Dr.Morgan unreasonably burdensome. But Rickover stuck to his guns, saying "I don't want our sailors to have any basis for worrying about the effects of radiation on anyone serving on our nuclear ships." (I wish Karl Morgan had stuck to *his* story. I've read some of his testimony in later years, arguing that even the permissible civilian dosages are hazardous.)

In other, less obvious ways, Rickover paved the way for civilian nuclear power. Starting with Shippingport, Admiral Rickover worked with Jim Terrill of the U.S. Public Health Service to have sharp, young public health officers stationed at key naval reactors sites. Dave Harward, whom many of you know, was assigned by the USPHS to Shippingport and later to the Mare Island Naval Shipyard. Thus, when it came time to draft a Pennsylvania state law regarding radiation, the state could turn to Harward as a public health official, rather than to the AEC, who might be considered biased. And when the Navy was asked by reporters whether nuclear ship operations at Mare Island shipyard might contaminate the environment, Rickover persuaded the Naval Operations people to step aside and refer the question to the local public health official. "Nobody will be reassured if the *Navy* tells them it's OK," said Rickover. "But the Public Health Service is responsible for the public health, and has no organizational bias toward the Navy." So Rickover had his people work closely with the Public Health Service, to satisfy them fully that we were indeed acting properly, and the Public Health Service in turn could then assure the public in a knowledgeable and responsible manner.

What this all adds up to is that Admiral Rickover viewed the Naval Reactors program from the start as an integrated piece of the whole national scene, encompassing several branches of the national government, the Congress, manufacturers, electric utilities, research laboratories, shipyards, universities and myriad other institutions. There was no precedent for a program of such breadth. It was as if Henry Ford had created not only the automobile industry, but also oil refineries, gas stations, highways, motels, roadmaps and the AAA. No one told Rickover to do this; no one told him how to do it.

The last two conversations I had with the Admiral, he knew he was dying and he asked, "How do you know what God wants you to do with your life? Maybe I was supposed to be a cello player. How do you evaluate it?" The first time he asked, the answer seemed obvious, and I referred to the kinds of accomplishments and contributions I have just been describing. But when I went back a week later, it occurred to me that the most impressive thing about Rickover's life is the fact that his whole approach was original and unprecedented. He had no model, no paradigm, no one else's experience to draw from. He wanted to use available commercial pumps, valves, pipe fabrication procedures, and the like, but he found them inadequate. So he developed his own. The same was true for training schools, shipyard organizations and manufacturing facilities. He imposed a philosophy of engineering excellence and created a formal quality assurance program for achieving it. Today, as American businessmen in other fields look in awe at the buildup of Japanese, Korean and Taiwanese manufacturing empires, they see much the same thing. The American nuclear power industry has learned much from Rickover, but there is still more to be learned. We should not leave our homework unfinished just because the teacher is no longer with us.

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He has written numerous books and technical papers, including the classic text, *Reactor Shielding Design Manual; The Rickover Effect: How One Man Made a Difference;* and *Creating the New World: Stories & Images from the Dawn of the Atomic Age.* He co-authored *The Shippingport Pressurized Water Reactor* and *Arms Control Agreements: Designs for Verification.*

He was co-founder of the *Princeton Engineer* in 1941 and is listed in: *Who's Who in America, in the World, in Science from Antiquity to Present, in Theology & Science; International Who's Who in Engineering,* and is a Life Member of the Philosophical Society of Washington, founded in 1871 by Joseph Henry. His works have been published in German, Dutch, Russian, Chinese, Japanese and Korean.