THE DEPARTMENT OF ENERGY ORAL HISTORY PRESENTATION PROGRAM

OAK RIDGE, TENNESSEE

AN INTERVIEW WITH JAMES K. WEIR, JR.

FOR THE

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INTERVIEWED BY

STEPHEN H. STOW

AND

MARILYN Z. MCLAUGHLIN (ASSISTANT)

OAK RIDGE, TENNESSEE

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TRANSCRIPT BY

BRIAN VARNER

STOW: Today, we're talking to Jim Weir, former division director for the Metals and Ceramics Division. Jim joined ORNL in 1955, earned his master's degree in metallurgical engineering from the University of Tennessee, and a bachelor's degree before that from the University of Cincinnati. He stayed with ORNL until 1994, when he retired. So, we'll be talking to Jim today about his experiences during his tenure here at ORNL.

Jim, tell us why you came to ORNL in 1955. What was the attraction and what was the job market like in metallurgical engineering at that time?

WEIR: At that point, the job market was pretty good. And, there was one other factor in my case. I was a co-op student at the University of Cincinnati, which is an all co-op engineering school, and at ONCO Steel Corporation in Middletown, Ohio. And ... I was there for my co-op periods for four years. The steel business seemed kind of dull to me, as steel businesses sometimes do to young people. So, I decided to go elsewhere. I interviewed here and there and decided that Oak Ridge was a fairly exciting place. And, it was not too far away from where I grew up. They offered me a job. So, I came here.

STOW: Well, that was only ten years after the war. Was there still a bit of a military environment around this place?

WEIR: Yes, there was, to the extent that there were anti-aircraft installations here and there around ... in-ground anti-aircraft rocketry. And, of course, they had just gotten rid of the guards at the gates in the previous couple of years --actually, a couple of years prior to that time. And, the place here -- it was varying by leaps and bounds, because the war was over, the bombs were over (except for the Cold War issues), and the Oak Ridge National Laboratory had been formed back in '46. All the laboratories, now DOE laboratories, were formed by the Atomic Energy Act in '46 and '47. I think there were two acts. At any rate, all that affected the environment here. It was a primitive town then. Of course, it was modernized considerably by the time I got here. Earlier on, if you look at the pictures, it was like the wild, wild West. You know, dirt streets, boardwalk sidewalks, huts, awful buildings, and other stuff ...You know how it was during the war. So, it was an exciting place to join.

STOW: What was your first job assignment? What programs or projects did you work on?

WEIR: At the time I arrived, the Aircraft Nuclear Propulsion Project was going pretty well. And, in the materials area, Bill Manly was in charge of that part of the division that dealt with the applied programs. The division director at that time was John Frye, who mainly was interested in the basic research part of the division. There have always been in that division the applied side and the basic research side. And, there was coupling between the two. There were two sides to the division that were quite strong in some areas. That was a benefit to both the basic research side and to the applied side. It was fascinating to have that mix all in one place.

STOW: Of course, at that time, ORNL was very much into development of various types of reactors, and one of the reactors, I think, was a molten-salt reactor. And, I think the M&C -- or the Metallurgical Division at the time, I believe -- was very much involved with development of high-temperature alloys for containment of those molten salts. Can you tell us a little bit about that work?

WEIR: Yes. The molten-salt reactor concept followed the Aircraft Nuclear Propulsion Reactor, in the sense that the fuel for the Aircraft Nuclear Propulsion Reactor was a uranium-beryllium-lithium salt -- a fluoride salt enriched with uranium as the fissile material. The evolution of that reactor system and the background required to learn about the corrosion of containment alloys by fused salt at fairly high temperatures (which had not been looked at very well before) --well, it hadn't been studied at all. And then, the adjunct things, like the secondary coolants, contained sodium, such as NaK, a sodium-potassium alloy. The issues that were dealt with in the Aircraft Nuclear Propulsion Project were the same ones that had to be dealt with in the Molten Salt Reactor Project. So, it was a natural follow on technically.

ORNL Director Alvin Weinberg was interested in a breeder reactor and the sodium fuel cycle, which was what the molten-salt reactor used. So, we had all the "horsepower" to deal with evolution of a molten-salt reactor system. The Aircraft Nuclear Reactor was supposed to run 100 hours and it did in a very successful test at very high temperatures, around 1350 degrees Fahrenheit. It ran for 100 hours with nuclear heat, with its own, self-sustained nuclear reaction. And so we succeeded there. But a different alloy was needed for the longer lifetime required of a commercial reactor vessel designed to produce power, and, in this case, breed uranium-233 from thorium. We used an alloy called Inconel. It was a nickel-based alloy with a high chromium concentration. It was oxidation resistant in air, so the outside of the reactor vessel would remain in good shape. The molten salts leached, or sucked, the chromium out of the inside surfaces of the Inconel vessel fairly rapidly. For 100 hours it wasn’t a problem, but for longer periods of time, it would have been. So, another alloy was needed. We knew it had to be a nickel-based alloy to withstand the temperatures of the molten-salt reactor, which were just a little lower than those of the aircraft reactor. And so, we began searching for an alloy that would meet two requirements.

STOW: Which are?

WEIR: The first requirement was that the alloy must not have a lot of chromium that could be leached out from the inside of a vessel containing the molten salt. The second was that the alloy must be resistant to oxidation from exposure to air outside the vessel. Coupling those two requirements was not an easy task. What it meant was that the chromium concentration had to be reduced to its lowest possible values in the alloy, yet provide for oxidation resistance on the outside. Now, we knew that nickel molybdate, which was the oxidation product formed on the surface of a nickel-molybdenum alloy in air, was a protective oxide film. And that was the key. So, we put molybdenum in a nickel-based alloy to provide oxidation resistance and strengthen the material. Molybdenum was a strengthening alloying element for nickel. And so, with all the compromises put together along with the necessity to fabricate from the alloy useful hardware, such as pressure vessels, piping, elbows, and tubing, we developed a new alloy called Hastelloy N, which is commercial today as Hastelloy N.

STOW: Who makes Hastelloy N?

WEIR: Hastelloy comes from Haynes Stellite Corporation, which became the Haynes Stellite Division of Union Carbide. There's another designation for the alloy: INOR-8, which stands for International Nickel (Company) Oak Ridge, alloy designation number eight, because it was the eighth alloy that was investigated. That's the only significance of that name. But INOR stood for International Nickel Oak Ridge. So, there were two companies involved in the evolution of that alloy. One was INCo, a big company, and the other was the Haynes Stellite Division of Union Carbide Corporation, another big organization with employees who knew a lot about nickel-based alloys, such as how to make them and how to get them in a composition that would facilitate fabricating the alloys into useful shapes. Hastelloy-N was one of the early examples of technology transfer at ORNL, and we did it in a very benign way. We didn't know what we were doing actually, but that's what we were doing.

STOW: Did it without knowing it?

WEIR: Yes.

STOW: Well, Alvin Weinberg, in his book, "The First Nuclear Era," refers to the development of some of these high-temperature alloys as examples of the most significant science ever done at ORNL. Can you expand on that a little bit? What sort of recognition did you get for that work, and where did it go in later years?

WEIR: The issues, of course, with the nuclear program were that the environments were different from what one normally finds. The major difference was the presence of neutrons. Neutron radiation is present in thermal reactors, like the pressurized-water reactors used today, like the molten-salt reactor at ORNL, like gas-cooled reactors in England, and like gas-cooled reactors being developed here, in addition to high temperatures. The classical radiation damage problem that occurred at low temperatures was due to the presence of fast neutrons that knocked atoms out of their normal lattice sites, and creating defects in the metals, and causing a type of embrittlement. At high temperatures, however, the type of embrittlement that occurred was mysterious for a while. Then it was determined that the embrittlement was due to premature fracture of the grain boundaries -- the boundaries between individual grains in a metal -- that at high temperatures are a weak link, anyway. But the issue was, why would embrittlement get worse in a neutron environment at high temperatures? Then we learned of the speculation in the Solid State Division by Jim Wilson -- J. C. Wilson. I don't know how he thought this up, but he did. He said, "I think the early fracture of grain boundaries is due to the presence of boron-10 and the production of helium by thermal neutrons." The boron-10 isotope has a high probability of interacting with a neutron because of its high cross section. As a result, a helium nucleus is formed. It then becomes a helium atom, which is gaseous. These boron-10 atoms generally reside in the grain boundaries of the metal. So, if the boron-10 is there, then the helium ends up there. That's the weak link. Helium is an inert gas that is very insoluble in metals so it forms little bubbles. Those little bubbles initiate early fracture in the grain boundaries, which is a weak link, anyway. The question was, well, was Jim Wilson’s theory really the case? So we did some experiments. Because there were calutrons at Y-12 that did uranium enrichment and other isotope separations, we were able to obtain boron with various isotopic concentrations of boron-10. The other isotope of boron is boron-11, which is more abundant and benign – that is, it does not interact with neutrons, as does boron-10. From the calutrons we were able to get boron enriched in boron-10 and depleted in boron-11. We doped stainless steels with various concentrations of boron to see if Jim Wilson’s prediction of a helium effect is correct. We found a significant effect. After irradiating the steel, we found that boron-10 was the culprit in the production of the helium. That was the result of those experiments. And, I've had people tell me since they read that literature, "How'd you guys think of doing that, and how'd you get it done?" And, I'd say, "Just accidental," in the sense that we could get the boron-10 in various enrichments, because Y-12 ...

STOW: Had the calutrons.

WEIR: You have to have all the pieces in one place to make things like that happen.

STOW: True.

WEIR: So, we got lucky in that regard. And, then the issue became, well, what do we do about that? So, if you look at the thermodynamics of boron and other elements, there are some strong boride formers --elements like boron chemically -- and one of those is titanium. Titanium is compatible with stainless steel. So, we added a couple of tenths percent titanium to stainless steels containing this boron, and we found no radiation effect at high temperature when titanium boride was present. Bingo! The problem was solved. That's all you have to do. And in some people's view, that was enough to make it happen. It was considered worthy of an E. O. Lawrence Award, which I got in 1973 for that work, a very satisfying experience in my life. So, new alloys evolved as a result of our work in on these materials -- the Hastelloy N and the stainless steel that's radiation resistant. We are now addressing the important issue of how to modify steels using modern techniques, such as the electron microscope, to provide a detailed understanding of what's going on in the interior of a metal. Fortunately, we have the advantages here of having large numbers of electron microscopes in our basic research program in the division.

STOW: Yes.

WEIR: And, later on, we had advantages in the applied side of the division, through the efforts of Jim Stigler. And, I think that probably occurred in the late sixties. So, we had all this horsepower in terms of the analytical capability of what's happening within a metal to guide us in the evolution of new alloys. And today, there are some very, very strong stainless steels that resulted from that kind of work at ORNL. Phil Maziasz of the M&C Division has developed a stainless steel that's extremely strong at high temperature. This work was based on the understanding of how its strength varies with temperature and what happens to its structure in very fine detail.

STOW: There had to be a transition in the 1970s as reactor programs died down. At that time the division found itself with all these microscopes and high-powered analytical equipment and staff. How did you transition from reactor programs to programs aimed at addressing other energy needs?

WEIR: Well, as you recall, in 1973, I think, there was the oil embargo.

STOW: I think that was '73.

WEIR: There was the Middle Eastern oil embargo and there were gasoline lines, and people were having trouble heating houses because of heating oil shortages. It was a terrible situation, so the U.S. government decided that it's time for us to get into other forms of energy production, other than fossil, other than oil, for many reasons. There was interest in alternative fuels for home heating and for automobiles and jet engines. Using less energy required development of more efficient devices, furnaces, refrigerators, houses, and so on. All these energy challenges required better materials, which were within the capability of the researchers in the Metals and Ceramics Division. We had a fairly large program here at the Laboratory that explored ways to improve thermal insulation of houses. We had excellent techniques for measuring the thermal conductivity of materials, which we developed earlier to determine the thermal conductivity of uranium oxide, which we needed to know for the reactor business. And so, we had that expertise, okay? So, we could deal with the energy conservation issue from the standpoint of comparing the thermal conductivities of different sorts of insulations developed for houses, refrigerators, hot water heaters, and other appliances. And then, on the energy production side of things, we looked at corrosion issues for materials proposed for plants designed to make gasoline from coal. The Germans during World War II made their own gasoline from coal.

STOW: They did, yes.

WEIR: They had a lot of coal in Germany. They had no oil. And, during World War II, they made gasoline for airplanes from coal liquefaction. So, we -- the country --got into coal liquefaction, and all the same issues, the corrosion problems, the high temperatures, were present in those kinds of plants. So, we in the M&C Division were a natural for addressing the materials problems of energy production devices. So work just sort of "fell our way," not exactly by accident, but because the efficiency of any machine depends on temperature. And, the higher the temperature in a production device, in general, the higher the efficiency is. And that's true in jet engines, in furnaces, in various processes. So, we had a natural built-in capability through whatever cause that fit all those issues.

STOW: Well, let's not say that it fell your way by accident. Let's say it was by design. Because you took over the M&C Division as division director in 1973, which is the year you mentioned in connection with the energy crisis. So, did you find that new job to be a real challenge, in transitioning from reactor technology to other energy forms? Was the change welcomed by the division staff? Tell us a little bit about your challenges then.

WEIR: Well, some of the challenges internally were psychological ones, of course. And those we could deal with internally. The external environment, the sponsors, the Department of Energy. In 1973 it was still the Atomic Energy Commission, which at the time had its first and only woman chair, Dixie Lee Ray -- a fascinating person. I don't know if you'd be interested in her or not. When I went to Washington to pick up the E. O. Lawrence Award, she was the person who was the chairman of the Atomic Energy Commission, and she presented the award to me -- she and her two dogs.

STOW: Her famous dogs ...

WEIR: And, they were with her all the time. And, she lived in a mobile home. So, she drove her house to work. And, when she came here to visit inside the Laboratory, there are funny stories around that. She insisted on bringing her dogs in the Lab. And, someone asked the question, "Well, should we badge the dogs?" (laughter) And, there were other issues that weren't so nice in the sense that some of the staff here at the Laboratory had to babysit the dogs, and they didn't like that at all.

STOW: What kind of dogs were they? Do you recall?

WEIR: I think one was a standard poodle, a fairly big dog, and I've forgotten what the other one was. But, they were running around everywhere. Everywhere she went, even on the stage when she was giving out the E. O. Lawrence Awards. She was a very casual individual, but she was very smart. She was a biologist with a Ph.D. in biology [from Stanford University]. After she left the AEC, she successfully ran for governor of the state of Washington.

STOW: She did. That's right.

WEIR: And so, at any rate, she was a very smart woman and a little strange, I have to say. That's enough of that story. (laughter) Now, where were we? We were worried about transitioning from the atomic energy business to other things. And so, you know, as fortune would have it, from the Atomic Energy Commission was created the Energy Research and Development Administration, or ERDA, as it was called. And, that occurred in 1974. The Office of Coal Research came to ERDA in 1975 from the Department of Interior. Also, the energy conservation effort was created within ERDA. So those things fit together. You know, I mentioned previously, we got into the conservation business, then alternative energy production. Fossil energy was seen as a source of alternative fuel because coal processing could produce liquids and gases – what we call coal liquefaction and coal gasification. And so there were a bunch of plants built, and we had a corrosion assessment team at these pilot coal liquefaction and gasification plants. A plant would get a component failure, and we'd send the ORNL team out because we knew it was going to be a corrosion problem -- it was almost 100 percent certain. Our team would find a corroded piece, bring it back to ORNL, look at it under the microscopes and other analytical equipment, and tell what the problem was. And, if it were a problem, they could tweak the chemistry of the system or of the temperature locally. We gave them enough information to fix it.

STOW: Good. Well, you introduced the concept of matrix management into the division during the 1970s, which is an interesting mixture between program management and line management. Was that intentional? Was that something that just evolved as a result of the challenges you faced? Expand on that a little bit, please.

WEIR: All right. Philosophically, change is difficult and is resisted by everyone affected by it. So, it wasn't just change willy-nilly. The issue was that the "customer base" had broadened. We had a lot more customers with various technical agendas. And, any division at the Laboratory, and the Laboratory itself, needed someone who could deal with a person in Washington who had the same agenda and could then arrange for things to get done at the Laboratory through its technical disciplines. Meeting this need required a "matrix organization." I wasn't a business school graduate, but I did learn some organizational theory at Cornell Business School, which I attended one summer in 1976. Prior to that time, I'd looked into the business literature and the organizational literature and learned about the matrix organization concept. A lot of it was the result of studies in the behavioral sciences. When you split the management responsibilities, it's very difficult on people. The military is a strict line organization with generals at the top. When Du Pont made only explosives before it became diversified, it had one product and one type of customer.

STOW: That's right.

WEIR: And, all the customers wanted the same product. So, it wasn't a big deal. But that all changed with the advent of the Energy Research and Development Administration in 1975, and later the Department of Energy. I think that was in 1977. So, it was a natural. And, the challenge was to teach leaders in the division to understand that they didn't have to master every management function to be able to manage the division properly, and that was hard to do, I'll tell you. At that time, we had the Union Carbide Management System, which described nineteen management activities. And, we'd take those nineteen activities and divide them, with some to the program side of the division, and the other to the functional technical side -- and it works. Then you could split them up, and it was a clear-cut line. And, once you did that, and trust that people know that's the way we're going to do it because "It's the only way we can survive in this environment," they will accept it. And, it's still that way in the division today. So, it's still that way in the division. It works every day. And, the whole Laboratory is organized that way.

STOW: That's right.

WEIR: So, I'm not sure ... I think parts of the Laboratory were that way before 1973, but, at any rate, the division wasn't that way at all. And, once things started changing in Washington, things just were a mess to deal with internally here. We had to change something, so that's what we did, and it works.

STOW: Well, it's worked well, because the M&C Division remains as one of the strongest divisions here at the Laboratory in some peoples' eyes, perhaps the strongest. Tradition persists. There's no question there. And, I want you to think back decades now. If you look at the present strengths and talents in the M&C Division, can you trace those back to the early origins of Oak Ridge National Laboratory, when it was Clinton Laboratories and the Manhattan Project was going on? Can you trace some of the current strengths back to the needs that developed for the Graphite Reactor and the other technologies that came along during those war years?

WEIR: Yes, the legacies from the war were fascinating. The Graphite Reactor, which first sustained nuclear reactions over the long term, was built in what is now the middle of the Laboratory. It had aluminum-clad uranium natural uranium metal fuel. The moderator in the reactor was very pure graphite. The process was to clad that uranium with aluminum and separate the uranium from the aluminum chemically, which requires some doing, and to learn how to weld the end caps on, so it didn't leak fission products out into the air, because it was an air-cooled reactor, and the air went right up the stack. Even then we were fairly careful about that sort of thing.

STOW: We are.

WEIR: So, the evolution of the fabrication process at the Oak Ridge National Laboratory didn't exist in 1942. But, they hired a lot of metallurgists here to do that. And then, after that they started up the plutonium production reactors at Hanford, Washington. Those graphite-moderated, natural-uranium-fueled reactors were based on the design of the Graphite Reactor but had a much higher power density. Now, what was learned fairly early on was that graphite in those reactors was exposed to a larger neutron flux and was not stable dimensionally in that neutron flux. Well, Eugene Wigner, probably one of the best physicists of the last century, said something like, "Well, of course, that's in accord with the theory." And, what happens is that graphite consists of sheets of carbon atoms. The atoms are tightly bound together in the sheet, but loosely bound between the planes, or sheets.

STOW: That's correct.

WEIR: Radiation damage knocks a carbon atom out of one plane, causing it to end up in between planes. As more and more atoms knocked out of their positions in the planes, the graphite would grow a little bit.

STOW: ... it swells up then.

WEIR: Yes, it swells in one direction, perpendicular to the planes. And, it's unstable. That's called "Wigner Growth" because Wigner understood what caused swelling of the graphite. And, another adjunct to that, in a sense, was that he was the first research director of this Laboratory. And, in

1946 he created the Metallurgy Division, the predecessor of the Metals and Ceramics Division, by pulling together all the metallurgists around the site, including the aluminum guys, who developed fabrication processes for making leak-tight slugs for the Graphite Reactor, and the graphite guys who were looking at the radiation damage in graphite. At that time, Doug Billington, who was subsequently the director of the Solid State Division, was in the Metallurgy Division studying the graphite radiation damage problem and doing other basic research on radiation damage using the Graphite Reactor neutrons.

The first director of the Metallurgy Division was William A. Johnson, who was a "loanee" from Westinghouse and a famous metallurgist who graduated from Carnegie Mellon University in 1940 with his doctorate. And, he was author or coauthor of a bunch of classics with his thesis advisor at what then was called the Carnegie Institute of Technology.. He left here in 1949, and John Frye became division director until 1973 when he retired. In the late 1940s the next step in the evolution of nuclear power involved the development and construction of "test reactors" for testing the ability of different materials to hold up under irradiation. The first such reactor was called the Materials Test Reactor.

STOW: The MTR.

WEIR: The MTR was built in Idaho. The fuel was developed here. It was aluminum-clad uranium oxide. There's another "Wignerism" here. They were having trouble in the flow testing of the fuel elements early on. They were flat plates, separated by water channels. The flat plates were buckling during the flow testing.

STOW: So, they curved the plates, didn't they?

WEIR: Wigner said, "Why don't you curve the plates a little bit and they won't do that." Sure enough, they don't. (laughter) The next reactors built here were the Bulk Shielding Reactor, the Low Intensity Test Reactor, and the Oak Ridge Research Reactor. We did a lot of testing of metals and ceramics at the ORR. We had instrumented facilities. In fact, my team put together the first instrumented materials radiation facility in the ORR fuel core. Back then things were done in the "pool side" outside the vessel. We wanted to get some high neutron fluxes, so we got inside the core -- very hard to do. It was a mess. Welding of aluminum is difficult at best, and, if you have to do it in thick sections, it's almost impossible. So, we had to build the first can to be about three feet long so it could contain the fuel elements. The can had to fit down in the same place a fuel element would fit, and it must be pressure sensitive to sufficiently contain the pressure if anything does happen inside. So, making that can, curving the heavy, quarter-inch-thick plates and welding the seams up, was a nightmare. And we had the two best aluminum welders in the Laboratory, who worked twelve hours a day for three days. It took both of them to do the welding. I was there most of the time. We finally got that can made and inserted it in the reactor core on schedule. But after that, we changed our approach and bought extrusions of these cans. They were big long sections that could be chopped up.

STOW: Single pieces, not welded, right?

WEIR: Yeah, a single piece. That’s very easy to do with extruded aluminum.

STOW: All right.

WEIR: So, once we decided we couldn't do it easily by welding, we looked for a simple way, and that was it. So after that time, everyone who wanted to run an experiment inside the core of the reactor used the aluminum can.

STOW: You describe a real history here in metallurgy and materials science. Is this capability at Oak Ridge National Lab rather unique, or does a similar capability exist at some of the other DOE laboratories?

WEIR: I think we have a unique capability here in the sense that we were very quick to meet the needs of the applied programs of the AEC, ERDA, and Department of Energy. We were very sensitive to the needs of the "customer." And, some of the other laboratories didn't do as well in that regard. The result is that the other labs don't have very exciting materials programs at this point. There's still at Argonne National Laboratory very good materials science done, basic research, similar to here in the Metals and Ceramics Division. Argonne and ORNL are the two main laboratories in this country presently that have major materials science programs.

STOW: One of the highlights of your tenure as division director had to be the development of the High Temperature Materials Laboratory, or HTML. Can you briefly tell us a little bit about how HTML came about and the length of time it took?

WEIR: Alexander Zucker was, in no small way, a pusher of that project. In the late 1970s when I was division director, high-temperature materials and energy production were the issues of the day. Our facilities were filled with equipment for funded projects and there wasn't any room to go anywhere else. And so we said, "Well, we'll have to build a new building if we're going to study these issues." And so, we started out in the direction of building what is called the High Temperature Materials Laboratory, which was to include research on ceramics and metals because, by 1962, the Metallurgy Division had been transformed into the Metals and Ceramics Division. The Metals and Ceramics Division had to hold fairly large ceramics programs, in addition to metals programs, involving high temperatures. So, the High Temperature Materials Laboratory name was born. It turns out that the ceramics program would fill the entire building. It's almost entirely a ceramics facility at this point, and it's a world-renowned user facility. If you go in there and look at the logbook on any given day, there are twenty or thirty users in there -- university people, industrial people, foreigners. It's a very popular ceramics user facility. Coors Technical Ceramics located in Oak Ridge because of the High Temperature Materials Laboratory.

STOW: Oh, is that right?

WEIR: Yeah. They wouldn't be here otherwise. I mean, why would they want to build here in Oak Ridge, unless there was some good reason. The reason was a ceramics user facility where they could get research and development done if they wished to.

STOW: How long did it take you from inception of the idea for HTML to actually opening the doors and getting research started?

WEIR: I think the concept development started in 1978, as I recall. I was still division director at that time. That's when we started discussions with potential sponsors and tried to get a coalition together. And then slowly a consensus arose and the usual process was under way. We got funding for design and settled on what would be in the building. So it took ten years from the time of the glow of the light bulb in the head of Alex Zucker and others until the building came online, which was in 1988. It was built on schedule at less than the estimated cost.

STOW: Amazing.

WEIR: And, the result of that was very fortuitous because the extra money still was there, you see. And, we could use it to buy equipment. The capital equipment budgets were slim at that point, so we did everything possible to spend the leftover money on capital equipment. That was a great benefit to have it happen that way.

STOW: A real coup. I wanted to ask you about the early 1970s. M&C staff were very much involved with the controversy over the emergency core cooling system for the reactors. There was some testimony given by division staff at the Atomic Energy Commission headquarters on the feasibility of using Zircalloy as a fuel rod element. Can you tell us a little bit about that and how the work here at ORNL affected reactor technology and the decision made by the AEC?

WEIR: Yes. Phil Rittenhouse and Dave Hobson were studying the zirconium oxidation processes to determine how Zircalloy corrodes in water and steam. And the Union of Concerned Scientists became concerned about how well the emergency core cooling systems in pressurized water reactors were operating and whether they could cool the fuel core in the event of a loss-of-coolant accident. They worried that a pipe in the vessel would rupture and that the cooling water would go away, leaving the reactor core covered with steam. The reactor would automatically shut down under these conditions, but the power that the nuclear reactions put out, as a result of the gamma heat from decaying fission products, is about ten percent of full power.

STOW: Okay.

WEIR: The fuel decays fast, but during that interim, you've got to keep it cool. And, there's a good reason for that, and, to me, it's kind of fascinating. That is, if you allow zirconium to be heated, and, if you don't sufficiently cool the uranium oxide inside the cladding, the temperature will rise, causing the zirconium to oxidize more rapidly. The oxidation process also generates heat. And, the situation gets out of hand quickly. The hotter the zirconium gets, the faster it oxidizes and the more heat it generates, like in a flash bulb. You don't want that to happen in a nuclear reactor core.

STOW: No.

WEIR: So, the results of those hearings were very strenuous. Phil Rittenhouse and Dave Hobson spent a lot of time in Washington, mainly Rittenhouse. Two other people from the Lab who spent time at the hearings were George Lawson, who was a heat transfer guy, and Bill Cottrell, who was in charge of Emergency Core Cooling Systems issues in the Lab's Nuclear Safety Program. So, those guys spent a lot of time in Washington. And, these hearings were called administrative hearings. That means the lawyers don't have any rules to go by. They can do whatever they want to. And, they do. You give them free reign and they will abuse people verbally, and they did. And, there's no judge there to say, "Halt," and it was awful, I'll tell you. And, Alvin Weinberg told Rittenhouse and Hobson, and, I guess, George Lawson and Bill Cottrell, "You go up there and you tell the truth and it doesn't matter ... let the chips fall where they will." That's what they did. And, it was very strenuous, mentally, for these guys, and I really felt bad for them. But, they went up there and gritted their teeth and did it. And, to this day, there's some sentiment that Phil Rittenhouse ought to get some sort of medal because he took a lot of abuse from attorneys on both sides.

STOW: Well, the AEC didn't like what he had to say, did it?

WEIR: Well, you see, he didn't know the total answer, and he confessed that he didn't know.

STOW: Yeah.

WEIR: And, it was a heat transfer issue and an oxidation issue.

STOW: Um hmm.

WEIR: He wasn't in a position to know the entire situation. The attorneys wanted to plant a seed of doubt on any issue, and that's what they were trying to do. And, the bottom line is, when the smoke blew away, two things happened. One was that the interim safety rules that the Atomic Energy Commission had generated and that the Union of Concerned Scientists were concerned about, were changed. New rules were put out. They were more stringent in terms of the cooling requirements, which was a necessity, I think. And furthermore, shortly after that, the Atomic Energy Commission was split up because it was both the promoter and regulator of atomic energy.

STOW: That's right.

WEIR: And that got changed as a result of the hearings.

STOW: Yes.

WEIR: I'm not sure if it was entirely a result of the hearings, but the following year, the Nuclear Regulatory Commission was formed.

STOW: Yes.

WEIR: This separate organizational entity was staffed largely by people plucked out of the Atomic Energy Commission. So there were two results of the emergency core cooling systems hearings. One was a change in the ground rules for reactor accident conditions, and the other was the creation of two agencies from the AEC – one to promote and develop energy sources and the other to regulate nuclear power.

STOW: Yeah, the Atomic Energy Commission was in a real conflict of interest situation, wasn't it?

WEIR: Yes, it was.

STOW: As we wind down, let me switch gears a little bit here, Jim. You've rubbed elbows with a wide variety of premier scientists and engineers over your tenure here at Oak Ridge National Lab. Can you identify a couple of individuals that really stand out in your mind as being real influences on your career and people that you admire greatly?

WEIR: Yes, I can. They're very clear-cut in my head, and those two people are Eugene P. Wigner and Alvin Weinberg. Now, I didn't know Wigner all that well, but what I did know about him, was all just superior stuff. You know, both he and Weinberg wrote this book called *On the Theory of Neutron Chain Reactors.*

STOW: Yes.

WEIR: I looked in that book one time, and I closed it very quickly.

STOW: (laughs)

WEIR: It was mathematically way over my head. But, those are two right smart guys. And Wigner was trained, formally as a chemical engineer.

STOW: That's right.

WEIR: He had a Ph.D. in chemical engineering. I suspect that all the physics he knew, which was a lot, he'd learned himself -- he was self-taught. Weinberg was a biophysicist by training but he ended up as a nuclear physicist. See, there was no nuclear physics prior to World War II.

STOW: That's right.

WEIR: So, they were self-created guys, self-made men, so to speak, technically. And, those guys were smart enough to pull that off. They were unbelievably perceptive. The physicist guys I talk to occasionally say that Wigner was a totally polite guy.

STOW: That's quite right.

WEIR: If you'd ever meet him, you'd like him instantly. He was a totally polite, kind guy, who never criticized anyone. However, I'm told, when Eugene Wigner thought you had done something wrong, he would say, "John, I don't quite understand what you're trying to say." And, the physicist would know right away he's made a mistake. (laughter)

Similarly, at information meetings that the various divisions used to have, Alvin Weinberg would attend them all, sit in the front row, and ask the most perceptive questions in fields outside his. At our division meeting, he'd ask guys questions that would make you sputter. And, our division researchers are very perceptive guys.

STOW: Oh, very much so. I think he has insights in disciplines that are far outside of his biophysics or nuclear physics background. I think he's essentially the reason why we have an ecological interest here at ORNL. And, he was very much into health physics early on, and so on.

WEIR: Yes, yes.

STOW: A very perceptive man ...

WEIR: And the Biology Division here, under Alexander Hollaender, was world famous, of course, and still is. Somebody had to hire Alexander Hollaender, who started this great program.

STOW: Yes.

WEIR: And, my guess is that would have been Alvin Weinberg. So, these guys, they're just unbelievable to me, unbelievably perceptive about a lot of things. Here recently, Weinberg was discussing the issue of nuclear waste, and his point was that we need to institutionalize the containment and the organization that will oversee the nuclear waste disposal sites. Now, he asked the question, "Since nuclear waste is going to be hazardous for ten thousand years, who will watch over it?" And his answer was, "It's got to be a religious institution. Religions are the only things that will survive that kind of time frame." And, he's probably right. Mankind's religious community is going to be around, and it's probably the best source of a long-term oversight of such facilities.

STOW: Well, there's some logic to that, but I don't know that the Catholic Church and the Pope are ready to take on Yucca Mountain yet. (laughter)

WEIR: Yeah, well, there might have to be a consortium of some sort.

STOW: We're getting signals out there that our time's about up. So, thanks Jim, we appreciate your efforts today.

WEIR: Thank you. I enjoyed it and I appreciate being here. Thank you.

END OF INTERVIEW