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**OAK RIDGE, TENNESSEE**

**AN INTERVIEW WITH SAM BEALL**

**AND PAUL HAUBENREICH**

**FOR THE**

**OAK RIDGE NATIONAL LABORATORY**

**ORAL HISTORY PROJECT**

**INTERVIEWED BY**

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STEVE STOW: Today we are interviewing two individuals who came to ORNL at an early point. Sam Beall came here in 1943 and was very much involved in early reactor development and later headed up the Lab's Reactor Division and then the new Energy Division. Paul Haubenreich came here in 1950 and got involved in early reactor work and then went to the Fusion Energy Division. Both of these gentlemen have interesting stories to tell.

How did you get interested in science and technology and when did you know what field you wanted to go into? Sam, we'll start with you.

BEALL: Back in high school I took an electrical engineering course that got me involved in technology and led me to decide that I wanted to go to engineering school.

STOW: You say in high school. Where was that?

BEALL: I was born in Plains, Georgia. There were two people there who were nuclear engineers and Baptists. Both lived in that town.

STOW: We had a U.S. president who came out of Plains, Georgia, didn't we?

BEALL: Yes. Jimmy Carter. His grandfather was our postmaster. Jimmy Carter was younger than I but I knew all his relatives.

STOW: So you knew you wanted to go to engineering school ...

BEALL: I intended to go to Georgia Tech but I ended up coming to the University of Tennessee.

STOW: Paul, what about you? Where did you get an early interest in this area?

HAUBENREICH: I was without a definite goal when I was in high school except I knew as soon as I turned 18 that I was going into the Army. I graduated from high school in 1943. The Army gave me a general classification test, which said, "You need to go to college and become an engineer." So, after basic training in Georgia, I was sent to Purdue University for an accelerated course in engineering. Unfortunately, they needed cannon fodder worse than an engineer, so I went through a time of combat in the infantry. By the time I got out of the Army, I resolved that mechanical engineering was something I wanted to do. I liked tinkering with things. So, I enrolled at the University of Tennessee in mechanical engineering.

STOW: Sam, you came to Oak Ridge National Laboratory in 1943, but you had been with DuPont before, I understand.

BEALL: I worked at a smokeless powder plant for DuPont after I got out of school. DuPont was trying to recruit people for the Manhattan Project. So, they sent me to the University of Chicago. I worked with Arthur Rupp, who was my mentor. We were

working in the west stands [of the football stadium] where the original [sustained] nuclear reaction took place [on December 2, 1942]. That occurred six months before we were there. We worked on smokestack dilution, developing formulas so we could predict what the radioactivity from the pile [stacks of uranium and graphite blocks] would be [when it left the stack]. Dick Fox [who joined ORNL later] had a lab next to us and did our tinkering for us. We got to know the [famous] people who worked on the graphite pile in Chicago [such as Enrico Fermi and Eugene Wigner]. We had quite a time there. We came to Oak Ridge in September 1943. Arthur Rupp and I were the technical backup group for the Graphite Reactor operating group. We tested the stacks to make sure they were operating as was predicted. We tested the uranium slugs to make sure they didn't leak. We inserted cans of isotopes into the reactor. When the reactor was thought to be able to generate more power [heat and neutron production], we invented some channel blockage devices that closed off some of the airflow to the pile and forced [the air coolant] to the center so the pile power level could be increased to three times its original level. That was in 1944 when all us DuPonters were sent to Hanford, Washington. That changed my assignment because then I worked on plutonium separation.

STOW: You must have known the magnitude of the Manhattan Project at that time.

BEALL: The first day I was at Chicago they told me what it was about and that we were just trying to make enough plutonium to make a bomb. Everybody on the technical staff at Chicago knew what [the purpose of the Manhattan Project] was. There was a lot of talk here about what it was all about but we never were in the dark about it.

STOW: Paul, what were you doing in 1943 and 1944? Did you know about an atomic bomb project?

HAUBENREICH: No. I knew something was going on near Knoxville. We picked up a hitchhiker one time and we asked him, "Where are you working?" because most men were going into the Army or to Detroit [to build tanks, planes, trucks, and weapons for the war using automobile assembly lines]. He said, "I'm working on a project next to Knoxville." He told me the name of the place. I had never heard of it. I said, "What do you do out there?" "I'm a pipefitter." "Well, what are they making?" "I don't know, but there are sure a bunch of 'em." So I knew there was something going on.

STOW: You came here and then went to Hanford and then you came back to Clinton Laboratories.

BEALL: After the U.S. dropped the atomic bombs on Hiroshima [and Nagasaki], Japan, we all got a letter from Arthur Compton congratulating everyone. [Beall brought a copy of the letter to the interview.] It is dated December 1945 and addressed to the Forty-Niners because that was the code word for Element Number 94 [plutonium]. So, he goes on to say how proud everyone should be for the four years of effort that was successful largely because of his management.

STOW: So, you came back here ...

BEALL: I came back here when Miles Leverett was the head of our group. Beecher Briggs, Richard Lyon, and others were in it. The reactor design at that time under Jim Lane and Alvin Weinberg was for the Materials Testing Reactor. We had a lot of tests going on fuel rods and fuel elements. They asked us to make a mockup of the MTR with a full-size tank and full-size flow. We assembled that thing and did the testing. When all that was done, Alvin called me in and said, “We have some fuel elements that Marvin Mann and Walter Jordan have used to do criticality experiments. You have been testing control rods and the metallurgists have beryllium blocks that are supposed to go into a reflector [to reflect neutrons back into the reactor core to help sustain the core’s fission reactions]. Can you make a reactor out of that?”

STOW: (laughs)

BEALL: A technician named J. J. Harriston and I were tasked to put this all together. We didn’t have any money, but we put concrete blocks around the reflector and poured tons of sand in the space between the blocks and the tank. We were ready to make the MTR assembly go critical in February of 1950. We were so nervous because there had never been a reactor fueled with enriched uranium go critical before. Just as we were ready to go critical after counting the neutron flow rate, this technician, who was a wag, blew up a paper bag and popped it like that. Everybody went to pieces. I almost fired him for that.

HAUBENREICH: This was a hydraulic mockup of the MTR that was converted into the Low Intensity Test Reactor [LITR] at ORNL. The actual MTR was built in Idaho.

BEALL: After the MTR mockup went critical in February 1950, we ran that reactor for several months. We finally increased the power level from 1000 to 3000 kilowatts.

HAUBENREICH: Where was [Navy Captain Hyman] Rickover at that time? [Rickover was later called the father of the nuclear submarine.]

BEALL: He was next door to the LITR at the Oak Ridge School of Reactor Technology [ORSORT]. LITR caused a lot of interest for Rickover and the submarine people. Walter Jordan got the *Scientific American* [magazine photographer] to take this photograph of what we call the “blue glow” inside the reactor. It’s called Cerenkov radiation, in technical terms. It ran on the cover of *Scientific American* in 1951.

STOW: That’s probably one of the first cover photographs that came out of ORNL. We’ve had an awful lot since.

BEALL: Right. In the photo you can see the control rods and fuel elements down there in the LITR. Eugene Wigner [Clinton Lab research director who had witnessed the first sustained nuclear reaction at Chicago in December 1942] had another name for the Low Intensity Test Reactor because we got it done on such a low budget. He called it the “Poor Man’s Pile.” He always called reactors piles because they had to pile up all the graphite blocks to make one originally [at Chicago].

STOW: And the LITR was the first reactor with enriched uranium. What was your involvement? Did you help design that?

BEALL: Not really. We had a design section and a development section. I was in the development section. The designers specified everything, like the [water coolant] flow rate between the plates [uranium sandwiched between aluminum cladding]. We tried to show they were correct [in their calculations]. The first fuel elements at that time were plain flat plates [arranged in parallel with spaces between them to allow flow of the water coolant]. When we were testing them, the differences in the water flow caused the plates to bend either right or left and dangerously close to the next one [so that coolant flow could be restricted, causing dangerous overheating of the fuel]. Wigner suggested, "Why don't we all bend them in the same direction [for structural resistance] to begin with? So, the Materials Testing Reactor turned out to have curved fuel plates.

STOW: The curved plates didn't bend after that.

BEALL: No. Right.

HAUBENREICH: The LITR was the direct ancestor of the water-cooled reactors used in Navy submarines.

STOW: That was my next question. We had the MTR mockup and the LITR and then others that evolved out of the early reactors.

BEALL: The submarine reactors had different fuel elements but they were water-cooled and had enriched uranium fuel and a lot of the technology in the MTR and LITR went into the design of the Navy's reactors. When Tom Cole was involved, he suggested that if the tank could be expanded, the reactor core could be put in a "swimming pool" so workers would have access to it without taking the lid off. [The water was deep enough to shield observers above from the core's radiation.] Tom was responsible for the idea of the "swimming pool" reactors and later the Oak Ridge Research Reactor. His idea for the 1955 "Atoms for Peace" conference in Geneva, Switzerland, led Charlie Winters and John Swartout to decide to move a reactor from Oak Ridge to Geneva.

STOW: Paul, you came to ORNL in 1950. What attracted you to Oak Ridge?

HAUBENREICH: The proximity to my girlfriend. Isn't that a good reason? I had gotten my B.S. degree in mechanical engineering in 1950 and I had a job offer in the rocket business in Huntsville [Alabama]. My pa said, "Huntsville is a long way from your girlfriend in Knoxville. Why don't you look into this opportunity in Oak Ridge?" "What do you mean?" "Reactor school," he said. "What's a reactor?" "Never mind. It's got a great future." So that's how I got here.

STOW: What happened to the girlfriend?

HAUBENREICH: We married. We've been married for 52 years.

STOW: It worked out well. It sounds good. Congratulations! When you first came here, Paul, what program did you get involved in?

HAUBENREICH: The first year I was a student at ORSORT, the Oak Ridge School of Reactor Technology. We mentioned that Rickover was in reactor school – he was here for only six months. I took a 12-month course on reactors, which is equivalent to a master's degree, starting in September 1950. There were forty students, twenty from the Air Force, Navy, Electric Boat Company, General Electric, Westinghouse, etcetera. The other twenty were school graduates. I was one of the twenty. There was an understanding that at the end of the year we would be free agents who could go anywhere. There was no nuclear engineering curriculum in the universities at that time. ORNL got the job of creating nuclear engineers. At the end of the year, all of the twenty had multiple offers. I was the only one who stayed at Oak Ridge. I chose to stay with ORNL and I was in the Reactor Experiments Engineering Division. Charlie Winters was the division director. I was working on the hydraulics of the Homogeneous Reactor Experiment (HRE) letdown, where you have a flashing flow of water and steam. There wasn't much experience on that. I was there from the beginning.

STOW: Did you two fellows know each other at that time?

HAUBENREICH: We got acquainted.

STOW: You were both on the HRE?

HAUBENREICH: Well, Sam centrally and I very peripherally. I was still working on the HRE-1 in development. It was not until the next reactor, the Homogeneous Reactor Test (HRT), that I became fully involved.

STOW: And, Sam, HRE-1 went critical ...

BEALL: In October 1953. And with the power, in October 1954.

STOW: Did you guys celebrate when the reactor went to power?

BEALL: We certainly did. Alvin, who was always good with a line when a reactor goes critical for the first time, opened a briefcase and pulled out a bottle with a black label and said, "Sam, when piles go critical in Chicago, they celebrate with Chianti. When they go critical in Tennessee, they celebrate with Jack Daniels." So we toasted everyone associated with the Homogeneous Reactor Experiment.

HAUBENREICH: You have to understand that Anderson County was dry. So a lot of people from Oak Ridge who went to Washington [for meetings] came back with more in their briefcases than they had when they left.

STOW: Yes, Oak Ridge had a history of bootlegging all the way back to 1943.

HAUBENREICH: We loaded up the airplanes with the stuff.

STOW: So, you guys celebrated HRE-1 as it went to full power.

BEALL: I have a picture of HRE-1. This was a simple structure. We had a stack of concrete blocks in a rectangular formation. The reactor was in the center of the assembly of concrete blocks, some up to seven feet thick. Over here was a steam turbine. In February 1954 when we obtained power level, we [turned water into steam to drive] the turbine. We generated 150 kilowatts of electricity. It was fed into the TVA grid. Charlie Winters, John Swartout, Alvin Weinberg, and I were there to throw the switch. We plated some keychain medallions together and gave everybody one.

HAUBENREICH: When did you get the steam whistle on the end of the building?

BEALL: The same wag that burst the bag at the LITR brought a steam whistle from a locomotive.

HAUBENREICH: Southern Railroad was switching over to diesel [engines] and junking their old steam engines, and he got this big brass steam whistle and put it up on the end of the building.

BEALL: We didn't really know that he had this done, but when we got the power at the HRE-1 and had all the steam going to the turbine, he pulled the whistle and it echoed through the building.

HAUBENREICH: Later on we were blowing the whistle at the HRT and Security called us to ask, "What's going on over there?" They could hear it over the ridge. They thought a train was coming.

STOW: What happened to the Homogeneous Reactor Experiment?

BEALL: The experiment was a success. As you know, Alvin Weinberg and Eugene Wigner had concluded that if we could get rid of the steps of fabrication and dissolution of the fuel elements, it would simplify the whole reactor idea. They promoted the concept of "a pipe, a pump, and a pot." It was more complicated than that. But the test of the HRE-1 came out so well. It was self-regulating and showed no corrosion problems. The test answered a lot of questions about the physics and chemistry [of reactor operation]. The word was out that we have to go to the next step. The idea there was to make a reactor that had a [thorium] blanket that could absorb [neutrons from] uranium-238 fuel to breed uranium-233 fuel. So people like Charlie Winters and Jimmy Lane in the reactor design section devoted a couple of years to refining the idea into the Homogeneous Reactor Test. We finally got that thing assembled. It started out pretty well except that we had a corrosion problem in the leak detection system. It did delay the operation for six months. Finally, we got it going. Things went fine up until after three months in 1955,

when we started this reactor. We got it up to full power and then all of a sudden it stopped being critical. We couldn't figure out what had happened. But a hole that had developed in the core allowed the fuel solution to mix with the heavy water [coolant] in the blanket. That was a real shock to everybody. By this time, Paul Haubenreich was in the physics analysis group.

STOW: Jump in, Paul, and tell us about your involvement there.

HAUBENREICH: To jump to the end of the story about the HRT, we felt gratified by our ability to operate it. My feelings were deflated during a visit by a group of utility representatives. We were talking about how great this would be to generate electrical energy. And the guy said, "You describe this uranyl sulfate fuel solution as something like sulfuric acid." We said, "Yes, there is sulfate and water." He said, "If you gave me a plant that produced hot sulfuric acid, I would not try to generate electricity with it." He had no interest whatsoever. But as a technological feat, the HRT was really something. Sam has kindly skipped over the fact that when we first raised the power level in the HRT, the uranium-233 seemed to go into hiding. As the radioactivity went down, we put in more uranium to concentrate the solution a little more. That was really a symptom of the Achilles heel of the concept. As the fuel solution was heated up, it separated into a dilute phase and a concentrated, much more dense, phase. That [concentration] was the root of a lot of our problems. The flow in the HRT was from the bottom up through a series of diffuser screens. It turns out that this heavy phase was collecting on the eddies on the side, generating intense heat. That's what burned the hole in the core.

BEALL: It was so hot that the wall of the Zircaloy vessel actually melted. We didn't know where the hole was at the time. We didn't recognize for some time to come that the phase separation had caused it. Later on we removed the diffuser screens where this had occurred. Eugene Hise and Bob Blumberg were the engineers who used tiny TV cameras and long tools to find and patch the hole. Actually, there were two holes because we had operated it with a dilute solution. They plugged up the holes and reversed the flow so the accumulation would not take place again. It operated for how many days, Paul?

HAUBENREICH: I don't know. It was a substantial number. We felt like it was a tour de force.

BEALL: It was 105 days.

STOW: What ultimately happened to the Homogeneous Reactor Test?

BEALL: Well, even though the accomplishments were great and the technology was advanced, there were difficulties, so the AEC hierarchy decided it did not want to put more money into that concept. The program was ended in the fall of 1961. I have a picture of the HRT. This assembly had concrete blocks on top that could be lifted off. We flooded the entire reactor with water and operated through water as shielding. The center inside was one big, steel tank.



STOW: When the HRT died, Paul, did you write an inscription to commemorate its death?

HAUBENREICH: We were at loose ends that day and spirits were down [back in 1959]. I got a big piece of paper and made an imitation gravestone. Because this concept had been intended to be a thorium–uranium-233 breeder, we thought something should be said about the termination of its great future. So, the inscription was: “HRT. R.I.P. Died a virgin. Never had a chance to breed.”

STOW: (laughs) I bet you were full of mischief in those days. Let’s move on and talk about the MSRE (Molten Salt Reactor Experiment). It came on after the HRE. Paul, tell us about how ORNL transitioned from the HRT to the MSRE.

HAUBENREICH: Another reactor experiment going on in the 1950s [at ORNL] simultaneously with the HRE was the Aircraft Reactor Experiment. The basis for that was the use of a molten mixture of fluoride salts, in contrast with the Aqueous Homogeneous Reactor, where very high water pressure was required to raise temperatures to 250 degrees Celsius. The pressure was 1000 to 1200 psi, or 30 to 40 times the pressure in your automobile tires. The Molten Salt Reactor has a very low vapor pressure so you could have a low-pressure system but [the molten salt is] at high temperature. The hitch is you have to have high temperature because salt only melts at 840 degrees Fahrenheit. And so you have to heat everything up [the material combining fuel and coolant] before you can do anything. For the Aircraft Reactor they wanted to pump the molten salt fuel to the heat exchanger in a jet engine. Instead of burning kerosene to heat the air, you would run the air across the heat exchanger. The ARE had a goal of operating for 100 hours continuously without breaking down. They did operate it for 100 hours. They shut it down. Then the Air Force and AEC supported the development of a larger reactor. They built the building (7503) and started on the reactor. They put in a vacuum tank and concrete cells for the salt fuel. Then the Air Force said you can make an aircraft reactor but you can’t get it off the ground because of the shielding. You can’t stagger into the air with that much weight. That program was canceled in 1961, after the HRE program was stopped. There was a blending, and the Molten Salt Reactor concept became ORNL’s next reactor experiment. The MSRE was not aimed at being an aircraft reactor but as a reactor that might be envisioned as an energy source for generating electricity. Again it was a low-pressure, high-temperature reactor that used a mixture of fluoride salts melted at 840 degrees Fahrenheit—lithium fluoride, beryllium fluoride, and uranium fluoride, which is quite soluble. (UF<sub>4</sub>, not UF<sub>6</sub>, or uranium hexafluoride, which is another story.)

BEALL: Herbert G. MacPherson was the major leader of the MSRE program. He came from Union Carbide’s Graphite Division, and he was the head of the ORNL Reactor Division at that time. He pushed the molten-salt concept. He and Ed Bettis, who carried the torch on the Aircraft Reactor Experiment, put together the MSRE program. Ed was quite a character.

STOW: But, there were problems with the MSRE, were there not? Or did the concept carry on with other reactors?

HAUBENREICH: There was no problem with the MSRE that compromised the validity of the concept as a possible future reactor. Although the work on the MSRE ended in the United States in 1968, there have been proposals in other countries for the resumption of work on molten-salt reactors. At ORNL there was an MSRE demonstration and an experiment to find problems we didn't expect.

STOW: Big difference between the two.

HAUBENREICH: You mentioned Herb MacPherson. The molten-salt concept needed a graphite moderator [to slow down the neutrons]. The Aqueous Homogeneous Reactor had a corrosion situation, so they needed to protect the vessel's steel wall from the sulfuric acid. The Metals and Ceramics Division at ORNL developed the INOR (International Nickel–Oak Ridge) alloy, which later became known as Hastelloy-N. The beauty of the concept was that the components of the fuel salt preferred to remain in that form in the components of the container and the graphite. The chemical potentials were such that they stayed the way they were. Corrosion was not a problem at all. But maintaining the reactor at high temperature was quite a feat. Many engineers and good construction—I could list an honor roll of people who deserve credit for this accomplishment. But ultimately we circulated fuel salt through the core for over 22,000 hours, or about two-and-a-half years. The MSRE was critical over 15,000 hours, or two years. One major advantage of the fluid-cooled reactor is that you could build the flow into the process. That was evident in the Homogeneous Reactor Experiment and the Molten Salt Reactor Experiment. Part way through our operation we stripped uranium from the molten salt. It started out with low-enrichment of the salt with uranium-235. The Laboratory was the repository for U-233. They had some that was bad stuff because it had U-234 in it. That meant it had many daughters that were very nasty—a lot of radiation. ORNL said, "We can process this into fuel salt in a hot cell and re-fuel the MSRE with U-233." Nobody had ever operated a reactor on U-233. We made up the fuel concentrate and put it in the reactor. Glenn Seaborg [discoverer of transuranium elements, chancellor of the University of California at Berkeley, and chairman of the U.S. Atomic Energy Commission], along with Ray Stoughton [an ORNL researcher], who discovered U-233 in California, came to the MSRE. We pulled the control rods and had the first and only reactor operating on U-233, right over the hill here.

STOW: And that was one of the early breeder reactors ...

HAUBENREICH: The concept of the MSRE was the basis for a breeder reactor. Both reactors—the HRT and the MSRE— were supposed to use thorium [in a blanket where it would be converted by neutrons emitted by the nuclear fuel to additional nuclear fuel in the form of uranium-233]. The Chattanooga shale that we are sitting on here has enough thorium in it that you could at a fairly reasonable price extract fuel right out of the ground. But Milton Shaw, head of AEC's Reactor Program, preferred another breeder concept, the Liquid Metal Fast Breeder Reactor [cooled by liquid sodium], a plutonium

breeder. At the end of 1969 Shaw sent word to ORNL to stop the operation of the MSRE and send back the money that you don't need for the fiscal year. Weinberg, Beall, and others calculated what it would take to pay the costs of firing Reactor Division employees. They said to Shaw, "If you shut down the MSRE now, send us more money." So we had a more gradual shutdown. But we did shut down the reactor while it was still operable.

STOW: Sam, you were division director for the Reactor Division at that point.

BEALL: I moved over there and took Herbert MacPherson's place in August 1963. I did that job for 12 years.

STOW: How did you like being a division manager as opposed to having your hands in reactor design and development?

BEALL: Well, I'm a better people director than technical director. We had so many programs going that we divided it up into project activities. MSRE was one. The nuclear desalination project was another one. We had the Army Package Power Reactor. Art Fraas and Don Trauger had the gas-cooled reactor project. These projects were all going on at the same time, and my job was to provide the [project leaders] with technical personnel. After the Molten Salt Reactor Project was canceled, the world was turning green in those years. In the 1970s the idea originated that ORNL ought to have an environmental program, so [Dave Rose from MIT] and later Jack Gibbons, an ORNL physicist, headed the program. I was asked by [Associate Laboratory Director] Murray Rosenthal to come over [to X-10 from Y-12] to start an Energy Division, which consisted of sociologists and economists – all new fields to me. Nevertheless, we put together a good team and worked on solar energy and geothermal energy projects and did environmental analyses. I was director there for two years and then Bill Fulkerson took over. I retired from ORNL in 1974, but Murray and I did a lot of things after retirement. We spent some time in Pakistan and India on the USAID (U.S. Agency for International Development) program.

STOW: So, your career took a change in direction in 1974.

BEALL: It was a fun change.

STOW: Paul, your career took a change, too. You went over to the Fusion Energy Division.

HAUBENREICH: Sam said he was a person director. I was honored in 1988 at the Martin Marietta Awards Night as Manager of the Year. I attribute that success to practices I observed and learned from Sam. I'd like to list other people who influenced me: Murray Rosenthal and Mike Roberts both had a lot to do with [my success in] my career. In 1973, three years after the shutdown of the MSRE, when I was working with Murray Rosenthal at the time, I had an opportunity to go into gas-cooled reactors or fusion. Floyd Culler, deputy director at the time, said, "You have a choice." So I

meditated and prayed over it. I said, "I believe I will go into gas-cooled reactors." The next day Culler came into my office and said, "I know we told you that you have a choice, but you made the wrong choice." He told me about fusion energy and its potential. Somebody else put the clincher on it. He said, "Fusion energy has a great potential. It's so great that the country will fund it for years, and by the time they find it won't work, you'll be retired."

STOW: (laughs) That's a good story.

BEALL: Have they found out it won't work yet?

HAUBENREICH: They haven't asked me lately. Fusion is an outstanding success as far as the physics is concerned. My questions have to do with [these concerns]. "Can you build a fusion reactor at a price you can afford?" "If it breaks down, can you fix it?" When I compare the complexity of a fission reactor with that of a fusion reactor, my answer to these questions is, "I'm not convinced."

STOW: Do you think the world or this country will end up getting fusion power reactors operable at some point?

HAUBENREICH: After I'm dead, I think. President Bush made a statement recently that the United States is back in the International Thermonuclear Experimental Reactor (ITER) program [to demonstrate the feasibility of sustaining fusion reactions using advanced engineering features]. Spencer Abraham, the secretary of Energy, mentioned that [the world will have] electrical energy from fusion by the middle of this century (~2050). That's probably about right.

BEALL: In the United States or somewhere else in the world?

HAUBENREICH: Somewhere else in the world. [ITER was to be built in Cadarache, France, it was decided.] [In the late 1980s] the United States, Soviet Union, the European Community, and Japan all were trying to get to that one goal (controlled fusion). They realized that not only in physics but also in technology, there needed to be a high degree of collaboration. We had started [on forming collaborations] here at ORNL on the Large Coil Task during that block of years between the MSRE and 1988. Those four parties started working on ITER. But in the mid-1990s the United States said that the ITER would not operate by the next presidential election. What good is it? If you can't have success that pays off at the polls, that's too long range. That's a little bit of an exaggeration, but anyway, the U.S. withdrew [from the ITER collaboration]. The other parties kept on. Japan needs fusion as a future energy source. The project went through the engineering design phase, and sites were offered in Japan, Canada, and France [the winner]. The U.S. rejoined the ITER project in 2003, but instead of one-fourth participation, we are in it to the extent of ten percent. China has come in with ten percent.

STOW: That's a mix of science and politics.

HAUBENREICH: That's a good point – the politics of science. The Large Coil Task was as much an experiment in international collaboration as it was an experiment in technology for developing toroidal superconducting magnets [to generate magnetic fields that confine the superhot fusion plasmas in doughnut-shaped fusion reactors called tokamaks]. It was a success. Everyone went home happy. [LCT was an international collaboration under the auspices of the International Energy Agency among the United States, EURATOM, Japan, and Switzerland.]

STOW: You were very much involved in that. I have a question for you, Sam. Paul just mentioned a few of the individuals who had influenced him through his career. Can you think of some individuals who influenced you?

BEALL: Well, I certainly can. My list includes Arthur Rupp, Dick Lyon, Beecher Briggs, Jimmy Lane, Charlie Winters, John Swartout, Murray Rosenthal, and Alvin Weinberg especially.

STOW: All famous names. As you look back on your career, as you first came here to the Clinton Laboratories, can you identify any one accomplishment that you are especially proud of?

BEALL: I think the [development and operation of the] Low Intensity Test Reactor and the Homogeneous Reactor Experiment were both something to be proud of because these experiments had never been done before. That's true of MSRE, too, with Paul.

STOW: You've been involved with more reactors than anybody in the history of the Laboratory, I suspect. What about you, Paul? Can you identify a particular accomplishment that you are especially proud of?

HAUBENREICH: Yes, I'm proud of the role I played in the international Large Coil Task, which tested six large superconducting magnets. Three were built under American manufacturers – General Electric, Westinghouse, and Convair. Three were from Japan (built by Atachi), Germany (built by Siemens), and Switzerland (built by Brown Boveri). Each of those partners had overlapping agendas and their own interests, as well. Because we were able to mesh all their hardware and put it altogether in a big tank over at the Oak Ridge Y-12 Plant and operate it, we satisfied the diverse desires of the international partners. That was a real accomplishment of which I had a part. The Department of Energy was not as confident as Laboratory management in my ability to handle it. So, for quite a time, we had in our daily planning sessions [Fusion Energy] Division Director Bill Morgan and Associate Laboratory Director Murray Rosenthal sitting in with the operators and scientists and me and second-guessing me. I was able to anticipate [what they wanted done], and they were pleased with the way things were going. It's interesting that the Germans, and to a greater degree the Japanese, had a respect for gray hair. I was able to sit at the head of the table and let the "children" all have their say. Then we'd say, "Let's try doing this tomorrow," and they would agree.

STOW: Sam, is there anything we have not touched on that you want to mention?

BEALL: Well, I think the Energy Division has a lot to talk about. I guess bringing together the diverse people and professions that formed that division did a lot toward giving this Laboratory a view of what's called the green world. That was a good accomplishment. Today the energy conservation effort is big here. Jeff Christian is probably running that program [mostly devoted to improving building, roof, and appliance energy efficiency]. It has turned out to be a national contribution. I don't know what has happened to the social scientists, but ...

STOW: They are still there.

BEALL: They are still there. That was a new thing for the Laboratory that turned out well.

STOW: Paul, is there anything you want to say as we wind down this interview?

HAUBENREICH: I would not want to stop without giving credit to some other people. In the Large Coil Test Facility, the interaction between ORNL and the Engineering Organization [managed by Martin Marietta Energy Systems] had never been done before at that level. Rosenthal was an important player in that game, as were Frank Patton, Phil Thompson, Martin Lubell, and Jim Luton. It was a demonstration of capabilities that had not been developed before.

STOW: Fine individuals. I'm glad you acknowledged their contribution. We're going to wind up. We thank you fellows very much. We had a fine interview. Thank you.

HAUBENREICH: It's been a pleasure.

BEALL: Thank you.

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