NASA Johnson Space Center Oral History Project
Edited Oral History Transcript

Henry "Hank" Rotter
Interviewed by Jennifer Ross-Nazzal
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Ross-Nazzal: Today is April 20, 2009. This interview with Hank Rotter is being conducted at NASA Johnson Space Center [JSC] for the JSC Facilities Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright. Thanks again for joining us today. We appreciate it.

Rotter: You're welcome.

Ross-Nazzal: I wanted to begin by asking you to give us a short history of Building 7 and how it changed to support the Space Shuttle Program.

Rotter: Well, let's see. Crew Systems Division moved onsite in 1965, and we moved into Building 4, but Building 7 was already there, and that was our test facility. It had three permanent vacuum chambers that are still there today: the eight-foot in the north end, the big twenty-foot chamber in the middle, and the eleven-foot chamber, which we built for Apollo. It was a LM [Lunar Module] Simulator at one end and a treadmill in the big part of it, so we could test suits and work metabolic rate for the backpack for the lunar surface on those suits and for the lunar suit. The eight-foot was basically used to check out the backpack, the life-support system for the lunar suit, and we did some suit testing in the eight-foot chamber also with the backpack, but it was really set up to check out the backpack function, and it's still used for that today for Shuttle and for Station.

For the twenty-foot chamber, at that time, we had a boilerplate Command Module sitting in it for Apollo, and we did suit testing and suit loop testing, interphases, in that chamber for quite a few years, even before the Apollo fire, maybe four or five years before the first Apollo mission, and continued to use it a little bit to check out stuff. Of course, as we started flying, then that became less used. I already told you the eleven-foot chamber was for the lunar suit.

Then at the end of the Apollo Program, in 1975—I worked Apollo all the way up through Apollo-Soyuz [Test Project, ASTP] and then moved over to the Shuttle group, and my first task was to develop the commode for the Shuttle and one other.

I had two things I was working on. I started supporting at that time, started working for their Water and Waste Management subsystem manager and supporting the Atmosphere Control subsystem manager and the Pressure Control System. So I was kind of a workaholic for all of those guys.

Then the Pressure Control System, we needed to do an end-to-end certification of that system, and we had different vendors building it, and Rockwell [International]—at the time, our prime contractor—hadn't had a vehicle yet to put it all together. So we decided to build that up into Building 7, and we ordered what we call the ETA or the Environmental Test Article, and that's that big, round can laying on its side down there. It's about twenty feet in diameter and maybe twenty feet long. We had Rockwell build it up, and they outfitted it a little bit, but they shipped it to us through the Panama Canal here, and we installed it. Had to build a path to get it through the Building 7 by those chambers, and put it at the south end of the building where we had room for it. Then we had Rockwell send us the internal dimensions of the Orbiter cabin, and we contoured it with the structural ribs of the inside cabin, you know, which is the structural ribs [which] supported the mold or the walls of the cabin that the crew could see. So we built that up. We put closed-cell foam behind it.

When we got through, we had an environment or a volume very similar to the Orbiter cabin, both flight deck and middeck and lower equipment bay. While we were ordering this, we had Rockwell build us an ATA, an Airlock Test Article, with a full-functioning airlock inside. The only thing we didn't have inside was some of the com [communication] stuff, but we replaced that panel, the com panel, with a fire emergency panel so we could human-rate this chamber, this airlock, and the ETA for human testing at reduced pressures, which meant we had to have a water deluge system in case of a vacuum chamber repress fire, which fortunately has never happened on this site. So we put the com stuff outside, but we built the inside with the pressure control, the fluids. I took the qual [qualification] water tank, installed it outside the chamber, but fed it into the airlock just like it would feed from the Orbiter cabin so when we did fill rate with water it would be the same.

We built up a complete pressure control system internally and externally. It had the pressure control panel inside the ETA. The qual panel, we put it in there. We put the supply panel which supplied both nitrogen and oxygen to the inside panel, where the crew could reach valves and change regulators and modes of operations on it so they could actually see. We put remote controls on those actuators so we could do this testing unmanned first, before we did manned. The airlock was built up where we could put a suit in it and the crew could practice getting ready to go EVA [Extravehicular Activity]. The outer hatch was the qual hatch on the Orbiter, the inner hatch was just a test hatch, but it had the flight hardware, the equalization valves, and the pressure gauges on it just like the flight hardware, but it functionally was just a test hatch. The outer hatch was identical to the flight hatch, except it wouldn't swing open all the way. But it was enough where the crew could open it up maybe an inch or so, so it would be like the pressure profile on the airlock would be same as the flight hardware.

They could go through the recharging of the suit, everything, the flow rates of the gases, the water coolant. We even built up a water coolant loop the same as the flight. We built the airlock depress valve and its vent path overboard the same, it was the same volume and dimensions of the flight hardware. All the profiles would be identical to the flight so that when the crew trained in it, they would see there wouldn't be any difference between actually doing it in flight versus what they were training on the ground.

So it was my job to get that hardware, help work with the test branch to make the inside and the spacecraft identical parts, and then, of course, they'd build up the facility part. In the meantime, we got two qual nitrogen tanks, thirty-nine inches in diameter.

We put two nitrogen tanks there, but we have four in the Orbiter, so we built a set of K-bottles up to simulate the other two, and then we had a set of K-bottles to simulate the oxygen tank that flew only for the first four flights, and then we took it off the vehicles. We had a requirement to be able to return the Orbiter in 156—no. The original requirement was like 129 minutes, I want to say. I might be wrong on that.

We had that requirement to return the Orbiter at 8 psi [pounds per square inch] in case we got a hole in the cabin, a half-inch hole, or actually 0.45 inch hole. We pressurized all the tanks up and put a valve in so we could simulate the hole in the cabin and went through our pressure control profile, where we let the cabin go down to 8 psi. We had simulated four crewmen en masse that were breathing oxygen at the same time, and so we set this profile all up. Then we verified we could hold and keep that cabin pressurized at 8 psi for that, I think it was maybe 156 minutes. Yes, I believe that's right, 156 minutes. We did an end-to-end test to verify one of our design requirements, which we couldn't do anywhere else except on a vehicle, and we didn't have a vehicle at the time because we were still assembling OV-102 [Space Shuttle Orbiter *Columbia*]. We were also doing OV-101 [*Endeavour*], which was the approach and landing test profiles and test. That vehicle didn't have a pressure control system, unlike the flight one. So this was the only place we could do it.

ROSS-NAZZAL: This is in the 1976, '77 time frame, then?

ROTTER: Oh, you want the date? Yes, let's see. We got the ETA, they were delivered in about 1978. We built this up, so we were doing this test in '79. Also, we put the cabin negative pressure relief valves in it. The Orbiter cabin has a requirement not to exceed 1 psi negative pressure during the entry, so we had these two big cabin pressure relief valves installed into the vacuum plenum, and then we did a maximum entry rate repress of the vacuum chamber, of the vacuum side, to verify those two valves could repress the cabin as fast as it was requiring.

Now, the two valves could do a half psi. One valve could do 1 psi. We had that redundancy there so any one of the two could do it, but we had a hard time getting the chamber—we had eleven-foot chamber plumbed in as our vacuum plenum to the vacuum side of the airlock and to the negative pressure relief valve. We had to do maybe three or four profiles before we could match the descent rate. The Orbiter falls like a rock until it gets down until maybe 20,000 feet, so we had a hard time getting the chamber to repress. We had to open up three emergency repress valves on the LM chamber to get the eleven-foot chamber to repress fast enough. It rattled the doors of the building when we did it, that's how fast we dropped. You know, that big building, we made a negative pressure in the building, just very slightly.

But we did that. That was the only place we did a cert [certification], the true cert test, where we repressed the actual volume of the Orbiter with that valve. It was all analytical before that, and here we went and did a test. Then the guys, we got together and wrote up the test report and the data, and then shipped it to Rockwell, and they put a certification cover sheet on it, then they shipped it back to me for my signature to prove that we had did indeed a certification test of the pressure control system to verify that.

Then in the meantime, we had this big ETA. An order went through all the Rockwell drawings in about, I guess, '79 for the air circulation system of the Orbiter cabin, and ordered all the piece parts and the ducting that required being built. Between the test branch and I, we built that all up, installed it in the ETA so we could circulate the cabin. One of the first tests, big tests, we did after we got that all set up, and we had the qual cabin heat exchanger, cabin fan, and we put all of that on the floor just like it was in the vehicle, and put a test coolant loop to it so it would emulate the water coolant loop to that cabin heat exchanger and stuff. Now we could control the temperature of the ETA, air temperature, and we could do the air circulation just like in flight.

When we put the 10.2 cabin psi, cabin pressure system in for doing the EVAs, to prevent bends during EVAs, so we could do the pre-breathe protocol instead of the crew wearing their masks for several hours before they go EVA, or being in the suit buttoned up and breathing pure oxygen for several hours—which is not pleasant, being in that suit for that long and not moving around, and it takes away the EVA time also. Or you have to change out the LiOH can, the lithium-hydroxide can that scrubs the CO_2 in the suit before you go out.

That added complications, so we worked with the medics to figure a different way to do the pre-breathe protocol, and that's when we put the 10.2 psi cabin pressure to go prior to EVA, where they would breathe on the mask for an hour while we depressed the cabin from 14.7 to 10.2 the night before. Then they would spend more than twelve hours at 10.2 before they go EVA, and while they were buttoning up the suit they would have to be at 100 percent oxygen before they depressed to the EVA pressure, which is about the normal time you would take to check out your suit and depress the airlock and all that. So it meant they just had to do maybe, once in a while, maybe a ten-minute delta wait period to get that full hour in before they were ready to go EVA, to depress the airlock.

While we had to repress that cabin from 10.2 back to 14.7 for landing, then we did a test. We put oxygen sensors several places around the middeck and the flight deck and did a repress, and we found out on our normal repress procedure, we'd built a nitrogen pocket on the middeck. It was right above the commode area and also on the middeck. By the hatch area and the commode area it was below the habitability limit; that nitrogen pocket momentarily was below it. If a crewman would have been there, he would have passed out. He might have gone farther than passing out, but I don't know.

But what had happened, we were blowing nitrogen in, and we pushed all this good air into the avionics bay, into the lower equipment bay, and up on the flight deck, and then to the airlock in the middeck area was too much nitrogen. So we went and changed the procedures, so we added oxygen and nitrogen together. We had two sets of regs, so we did the repress with oxygen on one and nitrogen on the other. The nitrogen one was in auto, so we would flow oxygen at the same time we were flowing nitrogen, and that kept us above the habitability limit. Then when we got enough nitrogen, that regulator switched over to oxygen. But by that time, we were pretty well repressed. The first test we did, we changed the procedures and found a problem and fixed it.

The ETA already paid for itself in that one test, and plus we did a bunch of other tests. We did airlock repress profiles, both emergency and normal. We put those in the flight data book and gave it to our MOD [Mission Operations Directorate] buddies, mission operations guys and flight controllers, so they could have a timeline and know what to expect, the normal operations of the equalization valves the repress valves, and the depress valves, what it all looked like.

Then for STS-9, we were going to fly a Spacelab the first time. I was the project manager for the tunnel adapter that fit on the back of the airlock and made it to the tunnel to go into the Spacelab. Now we had to have a pressurized transfer capability from the Orbiter cabin back to the back of the payload bay. That changed all our profiles, and we had to have another way to do EVA once this tunnel adapter made it to the airlock outer hatch. We put an EVA hatch on top of it, and now we essentially doubled the volume of the airlock by having these two modules, both about the same size as each other, mated together. We added a simulator to the airlock with piping, maybe a six-inch pipe, to double the volume of the airlock. We did those pressure profiles so we could know how long it would take to depress and repress and [to determine] when did we have to change the procedures when [we] opened the depress valve to the full open, so the time to depress from low pressure at 2 psi to vacuum wouldn't be too long. We tried to keep that repress/depress profile in a reasonable time, because that was taking away from EVA time. Trying to keep it down to ten to fifteen minutes total.

Then also, while we were doing it, we added an air duct where we could circulate from the Orbiter ETA cabin, circulate air all the way back to what would be the [Spacelab], because we were taking care of the CO_2 and oxygen and partial pressure and all control of the Spacelab. We built that duct up, and then we added the eleven-foot chamber, which turns out to be about the same volume of Spacelab, and we did a test to verify that we could circulate from the Orbiter cabin all the way back to this, I guess, thirty-foot tunnel to the Spacelab. Then we verified that would work. We put in our mixing valves and our ducting in to simulate the flight and it did work, so we were okay and ready to go in time for STS-9.

ROSS-NAZZAL: Were the ETA, the ATA, and the Spacelab tunnel adapter, were those the only changes that were made to the facility to support the Space Shuttle Program?

ROTTER: At that time, yes. This has got to be 1982 time frame.

Let's see, what else did we do? Then when we modded the Orbiter to move the airlock outside the cabin, which we already had the airlock in the ETA and ATA was an outside airlock, not an inside airlock, so we had to always calculate that little difference in the two volumes because the airlock wasn't inside the Orbiter cabin. It was on the outside in our test article. But when we got ready to go to [the Russian Space Station] Mir, we took the tunnel adapter away and took it back to the original configuration, now it was an outside airlock. Main reason, because we didn't need that anymore and that was taking up a lot of space and in the way. So we took that simulator, the tunnel adapter volume, off the ETA.

We did some mods [modifications] to work the Mir interphases. The Mir was so much later. We did it earlier for other reasons, and I can't remember the reason.

ROSS-NAZZAL: Extended Duration Orbiter, perhaps?

ROTTER: Well, yes. I was getting to that one, but I was trying to think. That was even later, too. We built the Galileo and Ulysses missions. We had to add another extra coolant loop to the Orbiter to cool them, because their heat load, with their little nuclear power plant RTGs [Radioisotope Thermoelectric Generator], were too big to add in directly to our coolant loop, so we had to rethink how we did that. I got a little bit ahead of myself.

About 1984 time frame, or '83—it was before the [*Challenger*] accident—we took all the qual hardware we had for the active thermal, the Freon coolant loop, which is external to the vehicle, and we built a test bed up with that. We simulated the radiator volumes by just tubing, but we didn't have actual radiators, but we had the rad flow controllers. We didn't have an ammonia baller, but we simulated it. We added the flash evaporator in there, and into an old g-Apollo test vacuum chamber, which was going to simulate the Apollo Applications module that we were going to do our first little Space Station with right after the end of the Apollo Program, which got canceled and never flew.

But we had this little g-Apollo, which is about ten feet long and maybe five feet in diameter, but it's just big enough to fit the flash evaporator in it. So we built that in it. We built up that coolant loop out there so we could do some testing. We were going to fly a mission with two different payloads that required coolant. One was a water coolant loop and another one was a Freon coolant loop, on the same mission together. When we analyzed that, the payload heat exchanger, we realized we had a need in the heat exchanger and the thermal profile where one payload was cooling the other up to a point before we were cooling them both. There was enough temperature difference between the return temperatures of those two payloads that one was cooling the other partway, and of course our coolant loop was cooling both of them at the same time. But we couldn't analyze that. I mean, that was too much dynamics in the heat exchanger to really have any confidence in the model of it.

We built that test setup out here where we simulated those two payload loops in the payload heat exchanger, and then we went and mapped that heat exchanger performance for two different coolant loops and two different heat loads, and we mapped multiple heat loads. We built up a map enough so now we could take that model and update it and upgrade it to analyze any situation that came along in the future. Of course, as it turned out, we showed that the heat exchanger couldn't handle that heat load and the two different fluids in it, and so we removed one of the payloads from that mission, and in fact we never did fly dual payloads. It required coolant ever since then. But we did learn how to do it if we had to.

We did fly two two water loops at the same time, one cooling electrophoresis in the cabin and one cooling the Spacelab. We had two coolant loops at one time through that payload heat exchanger, but they were both water and they were both well within the capability of the heat exchanger. The electrophoresis had a very low heat load on it, but they required coolant, and we did that for a few missions.

We had this Freon coolant loop all built up. Then along came Galileo and Ulysses, so we were plumb. We did analysis and all our homework, and we finally decided we could cool them by—in the GSE heat exchanger, we were only using one leg for ground cooling support to the vehicle. So we used the other leg to cool Ulysses and Galileo missions, and we built that up and simulated the tubing links and the building and everything, and built up. In fact, the payload office paid for our payload pump, and we built that loop up identical, and then added heat simulators to represent the RTG heat load. I forget which is which, but one of them was 3kW [kilowatt] heat load and the other one was 6kW heat load, compared to a normal Orbiter heat load of 12 to 13kW. So you were adding a significant heat load compared to normal. We built that up and we ran the launch profile and showed where we could do it and all that, and built that up into Building 7.

Of course, then we had the *Challenger* accident, and by that time we had done our cert test. Then we tore the RTG part out of it, out of the building, and while we were doing that, that's when we took out the tunnel adapter simulator volume out of there, because it was something we didn't need to test anymore and because it blocked a passageway around the chamber a little bit. So it was just a lot of cumbersome.

Then we started the Extended Orbiter design. I led that for the Crew System Division, both for the commode and for the CO_2 removal, when we built the regenerable CO_2 removal system that uses solid amine to absorb CO_2 and then desorb in a vacuum, and we didn't have to add heaters to make that happen. We built that up and we installed the RCRS, which is the Regenerative CO_2 Removal System, into the ETA, into the floor just like in the Orbiter. We plumbed it into the air duct, just like in the Orbiter, and we did initial testing to verify we could control CO_2 by simulating the crew loads and stuff, and learning how to control the humidity also, because it also removed some humidity from the cabin. We had to match that up with our cabin heat exchanger that also controlled that, then we put a bypass valve in there that was a setting for four to five crewmen, or six or seven, so we wouldn't dry the cabin out. It turns out when we did fly six, we did dry the cabin out a little bit. We got down in the high 20 percent range, which is a little bit dry, a little bit uncomfortable in flight. I always try to keep my crews as comfortable as I can, so I always remembered that. So we're building solid amine systems for the Orion and Altair, so that's very high on my list, not to dry the cabin out, to be one of those guys that makes sure they don't do that again.

We built that into the ETA. It has a vacuum duct that goes overboard, and the vacuum level we have at the RCRS is very critical for its performance, so we made it exactly that ducting, the same as we designed it for the Orbiter cabin, and we put the isolation valve outside of the Orbiter cabin. In case we got a leak in it, we could close off that duct. It was a one-inch diameter duct running across the cabin, so it could have been a pretty big hole in the Orbiter cabin if it got a leak. We built that all up in the ETA and then went and tested it and verified the performance was there, and we could control it, and we could get the performance we required and all that.

Then, you know, we had been doing a lot of testing with White Sands [Test Facility, Las Cruces, New Mexico] and stuff, to verify this solid amine wouldn't harm humans. Then we realized we didn't know whether humans could harm the solid amine, and the solid amine is exactly what it is. You put it on a little bead, and it's a little liquid gel on top of the bead to give maximized surfaces. It absorbs CO_2 and it's a weak bond to CO_2, then when you pull a vacuum it breaks that bond and the CO_2 leaves, and some of those bonds include a water molecule. Just to tell you how that worked a little bit.

We decided we'd better test humans against it, so we put seven guys in there first, put some cots and stuff in there so they could sleep in the ETA, and we locked them up at 14.7 for seven days, and tested and verified in the seven days that the RCRS or the CO_2 performance didn't change any that time. Then we did seven women for seven days, and we found out there were little differences in gas outputs from male than female, particularly if you had a baby. So there is a little bit of change there. But we saw no change, no affect to the solid amine, and so we flew that in the Extended Orbiter for six flights.

We had an in-flight failure on the first flight, and we went to the ETA, and the data we got off of it and the crew input, we went and made a mod in the ETA, a fix, and we verified it worked, called it up to the crew, read the procedures up. The crew implemented it and re-recovered the operation in flight. Then later on when we had the compressor fail, the check valve fail, I could turn the compressor off—which was a little air save device so you wouldn't vent but only half of that little bit overboard of gas. It was a gas saver thing. We went and verified it in the ETA and told the crew they could turn off the compressor and just vent the gas, all the gas, overboard, and we had enough gas to support it, and so we did that in flight. We did two real-time tests in there to show that we could handle that.

Then, after we moved the airlock outside to go to Mir, be able to dock to Mir—and, of course, later on the Station. We had a Hubble [Space Telescope] flight in there following that. With the outside airlock venting its pressure into the payload bay, when we captured Hubble and the first time we depressed the airlock, that gas impinged on the bottom of the bay and came up across Hubble and fluttered their solar panels enough to scare the bejesus out of those guys. So we went and worked with them. We had this equalization in the valves and the hatch, and it happened to have a little port where we could put a screwdriver to tighten the valve up when it's being built, or assemble the valve. So we taped up the normal air pass and used that little hole to depress the airlock. We went and tested that in the ETA and verified we could slow down the flow rate enough to what the Hubble guys were telling us we needed to get to, and we had Forrest Naumkin that did CDFD, air flow analysis and impingement, and he could do that in a vacuum. He did a lot of analysis for us, and we set up. He told us the flow rate we needed to get to, and sure enough, that little hole met that requirement.

We tested it and verified it worked, the flight flow rate, and then we read that procedure up to the crew and they taped it up, and the next airlock depress they did to work on the Hubble—I think they did three EVAs and the next two was fine. You couldn't even detect that flutter on the wings. Not visually. The Goddard [Space Flight Center] guys told me they could see a little bit, but not enough to bother them. There was a flutter fatigue factor that those solar rays would have collapsed that we didn't want to exceed, so there was another time the ETA paid for itself.

Then the next Hubble mission, we redesigned, we put in a cap that goes over the depress valve so we could select the flow rate and control it better than using tape and everything over a filter, over a screen to depress. We had a more manageable and smarter control feature to do that. Then we redid that testing in the ETA before that flight and verified that worked fine, then we met the flow rate. We redesigned our nozzle vent on the airlock. We had a T adapter, we had to come out into a T to be kind of non-propulsive. Well, we were impinging on the payload, so we weren't non-propulsive, and we just put a straight line out and that impinged less on the bay and less on the Hubble. We made that quick mod to the next flight that took the T adapter off the airlock vent and just had a straight vent, and it worked better and it was easier on Hubble. That's what the Hubble guys wanted, so we did it. But we verified all of that in the ETA first.

Then, of course, now we're going to go to Mir, and we were flying a SPACEHAB in the back. We wanted to circulate air also with the Mir, and we had the Russian docking mechanism on top of the airlock, and we moved it out further in the payload bay with a tunnel between the back bulkhead. We configured a little bit of that and did a lot of analysis on how we'd control that and just verify it by testing some of that, but the air mixing to both Mir and the SPACEHAB, and to the Russian docking mechanism, avionics under the floor of the airlock. So we did a little test out in the ETA to verify that we could control it with our normal cabin fan and a Venturi pickup on the middeck. Then we realized we had trouble getting enough airflow to Mir and to SPACEHAB at the same time—this is HAB now—and we added a booster fan. We took one of our avionics fans and verified it could boost up the delta-P enough to give us enough airflow so we could control the first module of the Mir and SPACEHAB and our tunnel and our crews, all at the same time, and below the floor the avionics also, air cooling.

So we did that mod, and with a little bit of testing in ETA to show us that we could do that. Didn't do a lot of testing on that, because we couldn't simulate all of that in the building. But we did enough homework to verify our analysis up front, or at least give us some data points. We didn't use the ETA for when we went to ISS, but since we'd been flying the ISS, we hadn't had to use the ETA at all. The crews now have had enough training, and procedures were down fine, that they said they didn't need the airlock training exercise anymore. They just needed preliminary training in the suit.

So we discontinued training crews in our airlock. Of course, then when we were flying the Space Station, they added a Space Station airlock and anteroom to the twenty-foot chamber airlock. The twenty-foot chamber had two airlocks, and we added that to one of the airlocks to simulate the Space Station airlock and anteroom—which the anteroom was the pre-breathe room, which is about three times the volume of the airlock on Station. They built that up and tested Russian suits in it and our suits in it, and the crew trains in both of those suits in that facility before they go EVA from Space Station. But that was another mod to the twenty-foot chamber.

The twenty-foot chamber, in the meantime, was reoutfitted with advanced ECLS [Environmental Control and Life Support], advanced life support and thermal control system, particularly a lot of advanced stuff before Space Station was built. We built up the regenerable systems, multiple different types of ones. We put a three-man crew—was it three-man crew or six? I can't remember. I think it was three both times, but we did a sixty and a ninety-day manned test in that prior to down-selecting all the options for Space Station in that design feature. So that was the big usage of the twenty-foot chamber.

Then one of the things we learned about it, that when you're staying for thirty or more days, you need the crew to be compatible with each other. We suggested to the Astronaut Office they ought to bring a few of their crew members over once in a while and let them stay together for several days and see how they get along with each other. They started doing that. They did that for a long while. One thing is to find out how to live isolated, especially for a first-time crewman that's flying, particularly if you're going up to Space Station for 90 to 180 days. So that's, I guess, the last use for the twenty-foot chamber, but you might want to talk to Reagan [S.] Redman and his branch about exactly how they used the later part.

In early Shuttle, prior to first Shuttle flight, Langley [Research Center, Hampton, Virginia] had an old, square vacuum chamber. We called it a ten-foot chamber. I guess its diagonal was ten-foot. We brought that into Building 7 and put it there between the twenty-foot chamber and the eleven-foot chamber. We built up the air circulation system primarily, the LiOH cans, lithium hydroxide cans, and the heat exchanger. Of course, the lithium hydroxide can have a little bit of charcoal in it to scrub out trace gases. We built that leg of the air circulation system together, and we went and verified the sizing of the lithium hydroxide, the change-out rate.

Each can is rated for two manned days, but we did testing for four, and six crews, and figured out how often we needed the change-out rate and that we sized the can right. You put one can in, and then you replace it. There's two cans in at the same time, and they're changed out twelve hours, normally alternately so each one is in there twenty-hour hours. But the first twelve hours you utilize about 80 to 85 percent of the lithium hydroxide. Then you'll leave it in for the next twelve hours, because you'll finally get more than 95 percent utilization, but the other can is doing the majority of the work. You're just topping this can off.

So we're utilizing to maximize the utilization of the lithium hydroxide; 99 percent utilization is not out of the ordinary. By that way, we save weight. We don't fly more cans because we're using all the lithium hydroxide up that forms lithium carbonate when it combines with CO_2. Also at the same time, we're verifying the flow rate and set up the bypass. I think 6 percent through of the total cabin airflow go through each can. We verified that, and we could control the volume in that. We did that in the ten-foot chamber, but long before we had the ETA built in there.

ROSS-NAZZAL: Do you know when that was brought in?

ROTTER: We started that in 1975 range, or maybe before '75, maybe, probably, '74 until '78. That may be the time frame. That's how long that was in there. Since then we moved that chamber to the back of Building 7, one of the annexes to Building 7, and we used it for a while to use plants to control CO_2. We did a one-man, thirty-day test in there with plants controlling the CO_2 level, and showed that could work. That was basically something toward maybe flying to Mars or are on the surface where you had plants to generate some food and also help you control the air environment.

ROSS-NAZZAL: When did Building 7 start transitioning from Apollo to Shuttle? You've talked about the ETA and then this ten-foot vacuum chamber.

ROTTER: We started that in the early seventies.

ROSS-NAZZAL: Around the time that Shuttle was approved, or a little later?

ROTTER: Right. Right after the Shuttle was approved. I guess we had a life support and active thermal concept in 1972 already on paper. That's when, right after that, we brought in that ten-foot chamber because we knew we had to get the lithium hydroxide utilization and profiles of that all set in place before we could even think about putting a final design on paper. So we had to test that out and verify that, and we went from a square can like this here on Apollo [demonstrates], we went to a nice big round can where we had actual flow instead of a straight flow through a path. We flowed down the middle and then outward.

We did some testing on the can by itself, but we wanted to test it now and the simulated volume and the simulated crew loads. We did all that testing, and we just did all this at 14.7 in that chamber. We never set it up to be a vacuum chamber, but we did it to test the Orbiter cabin CO_2 and a little bit of humidity control in there also, analysis. But we just verified the heat exchanger was sized right to reduce and control the cabin temperature and the humidity levels. That helped us set the control temperatures set point for the Freon coolant loop that cools the water internal coolant loops.

So we just simulated the heat exchanger. I'm not sure. We didn't do a whole lot of testing with the heat exchanger after that, but we did lots and lots of LiOH testing and set up our spec [specification], built our spec for the lithium hydroxide. We worked with the Navy. The Navy takes a wider range of lithium hydroxide performance, so we worked with them, and the Navy took what we didn't want, but we took what we wanted was in our dew point range for controllability and that worked great, because we never had a problem with the LiOH. It was just change it out, and we could predict how many cans that we needed to fly to do the mission. We built up a model of all of that based on that testing and later additional testing and in-flight data, and we built a model to give to Mission Operations guys so we didn't have to calculate how many LiOH cans they were going to fly. They can do that themselves.

But we used that test facility to verify all of that up front, long before we started building the Orbiter. We already had approximately the cabin size and crew size to work with, so that made it fairly simple.

ROSS-NAZZAL: Were there any challenges that you encountered as you were working on Space Shuttle, and you've got Skylab, and still a little bit of Apollo with ASTP?

ROTTER: Well, all of those things I told you were challenges! The biggest challenge was building the flash evaporator, but we didn't do that in the ETA, we did that elsewhere. After we built up that g-Apollo chamber was the flash evaporator. We did the Galileo and Ulysses certification testing, then we realized we hadn't—in the flash evaporator cert world, we did not do a maximum heat rejection test. I had the qual unit, so we went and we did that test in there, and verified that the flash evaporator could reject more heat way past its spec. The flash evaporator is the equivalent of a six-ton air conditioner. Most of your houses have three tons at the most, so it's a pretty good little beast.

We checked out several other problems. We had flash evaporators in this chamber here, and we had a second air controller affair where we realized we had a wire caught underneath the lid of the control box and we shorted, and we went back and verified that none of the flight hardware had that problem. So any failures we incurred in the ETA or in the Freon coolant test bed—since this was all qual hardware originally, built just as good as flight hardware—any failures we had, we always took back to the fleet and verified we didn't have that failure mode, or we could screen that failure mode. We treated the failures the same as a flight failure hardware failure, so we would always go back to all the flight hardware and verify that we were okay for that failure mode.

We had an issue with our cold plates, O rings, where they were swelling up in the Freon, and then when you deserviced the Freon, they would shrink, and they wouldn't swell up again as much because the Freon was displacing the elastomers in the rubber or the neoprene O ring. So we built up a little test bed with multiple different types of O rings, different materials, and we set it up in that Freon loop out there to test their compatibility with Freon, and did periodically deservicing and let them swell up or unswell, and then we'd pull the vacuum, we'd reservice the Freon, and see if they would leak Freon or not. We verified the neoprene O ring was the best we could use, so Rockwell and NASA and Materials and Process guys picked the right material originally anyway. So we did verify they did a good job, and so we continued to use those. But it was little things like that. We had an issue, and we could close the issue by doing some testing out there. That was one example.

In the Return to Flight, STS-26, we were required to test all our failure modes. We left water sitting in the flash evaporator in the flight vehicle at the Cape [Canaveral, Florida]. When we launched, then we had aluminum oxide coating and spots in that because of the heat rejection problem in the flash evaporator, so it was not meeting its performance. When we finally realized it was from the water, we went and we ran borescopes through this flash evaporator to verify we didn't have the same problem, and also learned how good the borescope—at KSC [Kennedy Space Center, Florida], when they looked with a borescope in there—how good they could see all the surfaces that we were concerned with.

It was good to have that hardware set up so when the Cape talked to me about a problem, and they called it a demoflachy, I could go out. Because I was calling this a gadget—I mean, I could go out and look at the hardware, and I knew—that was before we had web access—and I knew exactly what they were telling me now because I was looking at the hardware when we worked on a problem or something. So it was good to always have that hardware lying around at our fingertips to go out and look at, because now we understood what we were told. It also helped me ask questions also, back to, "Is this okay?" Or, "Is that the same as this hardware?" We could talk in configuration and detail. We could do it from drawings also, but the drawing doesn't give you that three-dimensional insight like looking at the hardware.

We had an issue with the cabin heat exchanger where we have a hydrophilic coating on the walls so when the condensed water on that side of the wall, the water wouldn't bead up high like it does on a waxed car. If it beaded up high, it would block airflow in because of lower flow rate. Also, we wanted it to wick across the surface over to where we pulled the water off the heat exchanger, so it would wick over to the holes we were pulling air off. We went and trained that water into that airflow path. What was happening to the flight hardware and the hardware I had here, that coating was sloughing off. It's kind of a spray-on foam like if you look at it, and it was sloughing off on time. We realized OV-102, cabin airflow rate has lost flow rate performance over the years.

We used a heat exchanger here to figure out how to do high-stream air jet-blow out the excess foam and blow out the debris that was caught in the heat exchanger. We did that test here first on a heat exchanger and then okayed the Cape to do that in the vehicle. Then sure enough, we recovered a 5 percent increase in performance, which is critical to payload integration and flying payloads, because we were flying SPACEHABs and labs, and the air flow was critical to the amount of cabin air heat rejection we could do. That was allowing us to fly a little more experiments and more payloads in those modules, because we could cool air better by gaining that performance. So that was another thing we used it for.

ROSS-NAZZAL: You mentioned reconfiguring the ETA several times. Was that something you did on a regular basis as payloads changed?

ROTTER: No, as the system requirement says. We built the Orbiter to do one thing, and the Orbiter is a very versatile vehicle, and we would come up with new ways or different ways of flying it or supporting payloads, and operations, and changed a lot of operations. We used it and reconfigured for those reasons, when we changed the operations of the Orbiter and the capabilities of the Orbiter. That was an advantage to having it here.

ROSS-NAZZAL: Have your operations changed at all in Building 7 for things like testing since you started with flight operations?

ROTTER: Well, that's a good question. I remember when I was a test director, we got away with murder. (Laughter) I shouldn't say it that way, but we didn't have all the—we were doing human testing, us engineers were conscious of safety but we weren't all-knowing, maybe a nice way to put it. We made some mistakes over the time, and as we progressed in years we improved the safety protocols and the pretest review, where we verified. We put more and more rigor into the test safety requirements and test presentation. Before you would do a test, you would make a presentation that you're ready to go do the test, and over the years that has improved maybe 200 percent.

We were young and new to all of this too. We had a handful of Navy Corpsmen helping us train the Brown & Root technicians who were doing the work, and to train them to be what we would call a certified space technician. We developed those processes over the years, and some of those processes migrated to the spacecrafts and the checkouts at the Cape and then building the vehicles, wherever we built them, assembled them.

But the safety protocol moved a lot. The rigor for manned testing is just much, much more strong or rigorous today than it was when I first started testing. I guess I did my first manned chamber test as a test director in 1965 on the vacuum chamber. Then I did the first test article on the centrifuge in Building 29, then I operated a drop tower until '67, when I moved over. After the Apollo fire, I moved over to Environmental Control and Life Support subsystem group, and I've been doing that type of function ever since. I'm the technical fellow for NASA for all of that.

But gee, that was a good question, because what we had a mechanical engineer and an electrical engineer, we built up our systems as good as we thought we could build them. Then we verified we were ready to test. The questions or the review process was a lot simpler than it is today. We made mistakes over the years, and we learned from them. We had Apollo and

Apollo testing. We had a suit hose blow off the pipe, and we sat a lip on the pipe to hold it on there. I was the block observer on that test. Okay, any other questions?

ROSS-NAZZAL: Well, I had a few more. You had mentioned a lot of tests that you guys did. Some varied as long as seven days. I was curious if you could give an example of the tests that you run out there, the type of tests, and how many people it takes to run a test, and the length of time. You know, sort of give an example or two for us.

ROTTER: Well, I remember we were testing the Apollo suit back in 1964, '65. Probably '65. It was a backpack, and that was one of the first times we were going to go down to the suit pressure of 3.7 like on the Moon, 3.7 psi like on the lunar surface. It was one of the first tests we did on the suit, and we put in pressure limit sensors so if the suit dropped below the 3.5, we would automatically repress the chamber. To do this test, then, we had the crewmen in there to do a little bit of exercise. We wanted to verify the backpack pressure control system worked properly. We plumbed it in with oxygen from outside the chamber so there was no issue of running out of oxygen, but we wanted to test the suit pressure control at that pressure.

I was a mechanical engineer on that; we built up our plumbing and stuff to support the backpack and the tubing and hoses and all that. Then we had an electrical engineer that built up the instrumentation and put in the barrel switches and all that. There was us two NASA engineers plus our lead guy in the branch. I guess he was the Deputy Branch Chief at the time. Then we had a couple of NASA technicians supporting us on instrumentation, an electrical guy and a mechanical guy, and plus maybe I guess two, a couple of mechanical techs and maybe three, a couple of electrical technicians, and that was the test team we put together. Then we had

QC [Quality Control] there to help us document the procedures and help us document the data, and we built this up and set it up in the chamber and that was kind of it. I still have some test reports around here somewhere.

ROSS-NAZZAL: Do you have an example from the Shuttle Program that you can tell?

ROTTER: I didn't do any manned testing in the Shuttle.

ROSS-NAZZAL: Oh, okay.

ROTTER: I wasn't the test director. We did in manned testing, but I was the customer in the testing. So I didn't work the test side; I worked the hardware side. I was responsible that the hardware was ready for test, but the test setup and all that was the responsibility of the other side of the house, so I can't really answer that because I didn't take that much part in that part.

ROSS-NAZZAL: Sure. I just have a few more questions for you. One of the questions I had relates to the DOD [Department of Defense] flights. Did that have any sort of impact on your facilities at all in terms of flying classified missions, or was that a non [issue]?

ROTTER: No, that was not an impact here at all. It changed the way we handled flight data, but that did not affect any of our testing up front.

ROSS-NAZZAL: When was the ETA last used? You mentioned that they don't use that anymore. Do you recall the date on that?

ROTTER: I used it for the last Hubble flight, preparation for this one [STS-109]. They flew in March of 2002, and we did the testing I guess late in 2001 where we verified that depress valve and—oh, wait a minute! There was another, oh, yes, the last test. Now I remember. The last test was for Space Station. I guess in about that same time frame, 2001 also. Those two tests are very close to each other. At the end of 2001, the pre-breathe in Space Station, they hadn't set the anteroom up, and pressure control or the protocol for bends prevention was still kind of in flux and working. So what we did was when they went in the anteroom, we depressed it to 10.2, and they needed the oxygen masks.

At that time, I think there was a pressure control. They didn't want to use their high pressure oxygen for that because we would deplete it, and that protocol would use about ten pounds of O_2 per crewman. It's twenty pounds, and that would require a lot of pumping of the oxygen from the Orbiter back up to 3,000 psi, and we had a life de-arcer that was the compressor. It was life-limited, so we didn't want to use that. We had breathing mask stations in the Orbiter middeck, and what we did, we put in a sixty-foot umbilical, and it would reach from the Orbiter all the way to the airlock anteroom, where the crew could hook up to it and put on their masks.

Well, the issue was when we first tried it in Station, we had a pressure drop where we saw we weren't giving them enough pressure at the mask, so when they would inhale they could pull in cabin air up the side, across the mask. The masks are anti-suffocation, so you can't suffocate in it. So we needed to increase the pressure. We plumbed that into the Orbiter middeck where we had 100 psi to feed it.

I'm trying to remember what we changed. Well, we hooked the mask up on the umbilical, and instead of reducing the—yes, there was a reduction of 40 psi somewhere downstream. Instead of doing that, we let the mini-reg at the mask do the reduction in the pressure, and we fed 100 psi all the way to the mini-reg. We verified that the flow rate of the Orbiter could keep up with that mass usage and maintain enough pressure at the mini-reg so you wouldn't pop the anti-suffocation valve.

We used that procedure for quite a while; ROFU [Remotely Operated Fluid Umbilical] was the name of the umbilical. But we did that for several years until we came up with another alternate, and Space Station figured up another vent line to feed that mask and changed the procedures. I don't think we do that today, but we did that for, I don't know, maybe four or five Shuttle flights to Station, or maybe longer. Those two tests were the last two tests in the ETA.

Oh, that's what it was! I had a 900 psi test port in the airlock, and we plumbed it to that. The 100 psi wasn't enough to maintain that pressure in the hose, and we put a regulator downstream of 100 psi to reduce it, and we verified we could control the pressures that way and still feed enough oxygen to the crew. Then we did a test before that for the—we built an O_2 transfer line from the Orbiter to the—well, no, we never put that in the ETA. We did that elsewhere. Excuse me, we didn't do that in Building 7. I've got to remember all of this.

ROSS-NAZZAL: Well, it's been a long time that you've been working here.

ROTTER: About twenty-seven years working the Orbiter, then another, I guess since I've been in this organization, another five and a half years looking over their shoulders. So it's a lot of stuff to remember.

ROSS-NAZZAL: Sure. Who were some of the main contractors who were working in the facility for the Space Shuttle Program? Do you recall?

ROTTER: It was Brown & Root up until some time frame. Whether they were there all the way into Shuttle, I don't think so. I think they changed, somebody else won the contract. But Brown & Root was like for the first 15 years, and then they formed a partner with somebody. I think it was Brown & Root & Northrop for a while. You would probably need to talk to Reagan Redman in the company to get the names of the companies and stuff.

But that was interesting in the early days. We as engineers worked with the technicians to help train them, and they trained us, and we worked together. It was very important for us to work with our technicians, especially in building test beds and test setups. I still have a lot of technicians that are still good friends of mine and I still value a lot because I learned a lot from them.

ROSS-NAZZAL: Who else besides do you think we should talk to if we need to find additional information about Building 7?

ROTTER: Joe [Joseph J.] Kosmo. He did the suit testing, a lot of suit testing over the years. Ralph [J.] Marak was in the test branch for a long while. He's still here. Maybe Pat [B.]

McLaughlin. Let me see. Who was in the test branch? Most of the guys in the test branch there today came from Building 32, and wasn't involved in the early days, in 7. I don't know of anybody up there still anymore.

The one big change, that change in the test procedures, NASA did all the writing the procedures and building up, designing the test bed or the test setups, and then over the years a lot of that has transitioned to the contractor. It was NASA-overlooked, but today the contractor has their own set of engineers that do all of that and to help set up and do all the design work and procedures, even helping write the test reports. So that's changed a lot since, because we NASA engineers did it all back in the sixties and maybe even into the seventies. I left the group in '67, so I don't know what happened after that. My main job until the time of '67 was to help build the centrifuge, but in the lull times I did vacuum chamber testing. Then we built a drop tower in there.

Oh, yes, the drop tower! That was in Building 7 also. It was a sixty-foot tower where we dropped a platform with a piston on the end of it into a cylinder with hydraulic oil in it and with maybe 360 pins around in that cylinder. We could pull the pins out based on a computer program to give us anywhere from a 5G to a 100G profile with a triangular waveform or a trapezoid waveform or a sinal waveform, whatever the test requester wanted.

We did some avionics equipment testing on that. Apollo had a 78G crash load requirement that the hardware wouldn't come loose and fly across the cabin. We did a lot of testing for that. Then in Apollo we had attenuated struts on the couches that would, if we had a hard landing, the struts would stroke and keep the G-load on the crew below 20Gs or near 15, actually was the design criteria. One Apollo mission landed, it was only two chutes. One chute failed, and we did stroke one of those or a couple of those struts down on that mission landing.

But I did the drop tower testing for that and we dropped, I don't know, in one day and a half we did I think eighty drops, where we'd drop in compression, and then we would reverse the strut and drop it in tension or in compression. First we dropped it in tension, which is the stroke direction, and then we dropped it in compression, just reset it again, and then did it again. I did the qual test on that.

Then we built up a set of couches on it and put dummies in it like Apollo couches, and we dropped that again with the struts supporting all the couches, six struts supporting the couches just like in the Command Module. We did a couple with dummies on it. That was instrumentated with accelerometers, and we did that test. We didn't need that for Shuttle, so that was the reason it finally was—we used that drop tower height and stuff to string the Galileo and Ulysses coolant loop up and down that, and put the Galileo heat assimilator at the top of that tower just to give us the room to add all that tubing length and get the flow straight past, so we would be similar to a vehicle. We built it up in that thing, but later on they removed the drop tower out of there.

I remember we did a drop test somewhere in 1 or 2, somewhere for Shuttle, for some avionics, but all I remember is they called me out there. They had a problem with the drop release mechanism, and I went out there and fixed it for them. But I can't remember what the test subject was, or item. That was in about '77 or something. I know I was working on Shuttle already then when I had to do that. That was probably the last test that the drop tower was used for.

We did a human drop test on it for Apollo landing, for the LM. We dropped it from about five inches or six inches high and took four feet to stop it, to simulate a landing in 1/6 G on the lunar surface. What we wanted to see in the LM there was the crew was standing up with bungee cords holding them in place on the floor standing, with armrests underneath their forearms so they could handle the controllers. Those armrests had to support them when the vehicle touched down on the surface, and we did a test to verify they wouldn't go all the way to their knees and that armrest was adequate. That was the only human test we ever did on that drop tower. Dropping somebody from six inches is not a life-threatening thing, but it would prove that the armrests did work, so that was interesting. I didn't do that test, but I helped set it up for them. I was already in the Command Module group when I did that. That was about '68 or so when we did that.

ROSS-NAZZAL: Do you have any papers, memos, books, anything like that about the facility that might help capture the history, especially in relation to the Space Shuttle Program, that you could share?

ROTTER: I have a flight acceleration book that was on the centrifuge. I don't know if I have anything on Building 7 as such. I have that test report from the ETA certification testing. I don't think I have anything that's like what you're asking for. Since Rockwell and us, we helped put it all together and everything, we both knew what it was and we were the only users of it, so I don't think we ever advertised it. Today, they've got those documents and description of all the different chambers and test facilities on the Internet, and they're advertised. But I don't know if the ETA ever made that list.

I was on the [NASA] Headquarters team to look at vacuum chambers for Constellation and future telescopes testing, and [to look at] what the agency needed to do in vacuum chambers. I pulled all that data on the vacuum chambers out, but I didn't see the ETA on that list. Because it's not a "vacuum chamber;" it's a test article. So it wasn't on that list because of that. But it may be written, may have been written up by someone else, but I didn't do it. So I don't know about it.

ROSS-NAZZAL: All right. Well, we thank you very much for your time today.

ROTTER: You're welcome.

[End of interview]