NASA GLENN HISTORY OFFICE
ORAL HISTORY TRANSCRIPT

NEAL WINGENFELD & DOUGLAS BEWLEY
Interview by Virginia Dawson
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DB: Doug Bewley
NW: Neal Wingenfeld
GD: Ginnie Dawson

DB: My name is Douglas Bewley, and I worked at the RETF Rocket Engine Test Facility located at NASA Glenn Research Center in Cleveland, Ohio.

NW: My name is Neal Wingenfeld and I worked at the rocket engine test facility in the South 40 area of the NASA Lewis Research Center.

NW:
I became involved at the RETF facility South 40 back around 1966. I had been on the lab about three years, but was mainly working over in the Propulsion Systems Lab on the RL-10 engine working at Plum Brook and the JK sites, and working in the old rocket lab, and they wanted another electrical...electronic engineer to help out in the RETF facility, so my supervisor asked me to start working over there part-time in addition to my existing duties, and so they got work in there, got involved more and more with the facility, where it became my dominant project for many years after that.

When I got involved back in the 60s and into the 70s, the primary research going on at the facility was combustion instability with liquid hydrogen, rocket fuel, mainly liquid hydrogen, liquid oxygen rocket engines. They were concerned with combustion instability and quite a bit of the work we did in those days was with combustion instability. They were very concerned. They were pushing hydrogen as their rocket propellant, and they found out that cold temperatures they had to be very, very careful with the design of the engine because they could propagate combustion instability very easily.

Combustion instability is uneven burning in the combustion chamber. Instead of getting the smooth chamber pressure, smooth thrust out the nozzle, you get oscillations or pressure oscillations that are very destructive, and you have to be very careful. You don’t want to have those. So we would work on the different various configurations, and different temperatures, different pressures, different flow rates, different configurations, how can you dampen out the oscillations.

DB:

An interesting thing too is that what they used to do is in order to induce combustion instability to be able to test it, Neal came up and a lot of the operations guys came up with some configurations.

NW: We had some unique configurations...

GD: Could you start again?

DB: One of the ways that they induced combustion instability in the test engines at the facility which was pretty unique, Neal and a lot of his co-workers came up with machine guns that were blasted into the combustion chamber to cause instability, and I will let him digress on it, but they had to induce combustion instability in order to test the theories to stop it.

NW: We had some unique engineering concepts that we came up with to induce the instability to find out, is the configuration stable? Because a lot of times it was on the hairy edge if you like to use that term. And so what we wanted to do, we would fire the rocket engine, and then we would induce pulsations into the engine, and if it would dampen out that dynamic pulse that we would put into the rocket engine chamber during combustion, we knew that the configuration was stable then. So we had various ways. We had machine guns, and we had cannon hooked up. We had a sinosoidal (?) pressure generator, and then we came up the idea of exactly put pyrotechs or bombs. And so we put bombs around the rocket engine chamber. And with the advent of the computers that Doug and I would come up with to control, we could time these things down to a millisecond. And we would set off these bombs around the chamber and try to induce combustion instability.

DB: That work continued, even the bombing was the way we did all the way up through the end of the program, the test programs at RETF. The TRW program which we will get into later. We used that to induce instability into those engines too.

NW: The Air Force out at Edwards has come to us and asked us to help them when they were doing some of their rocket tests in the 90s. We sent our circuitry and our technology down there for them to use on some of their rocket facilities. So we were forerunners of doing all this type of work with combustion instability.

In the 60s, before computers were available, they used strip chart recorders with all the data was recorded in an analog method. And as the technology improved with computers, we started going to digitizing the analog data and putting in digital formats into computers. And what is still called today, we called it a DDAS, which stands for Digital Data Acquisition System. And we, as the technology improved, these systems became better and better and better. The accuracy, the speeds with which they could digitize the data, which means the bandwidths, which means we got better data, and the digital systems just overwhelmed the analog systems. And now all the data is taken into a digital format. So at South 40, Doug, you want to pick up here a little bit.

DB: Well, the interesting thing about the transition, we had older operations engineers that were still used to the analog data. So even though we had a digital system, we still used some strip chart recorders, because it got them immediate feedback, and they were also used to using them. Now, if you go into our facilities, everything has been modernized. Some of the other facilities are burning similar tests. Everything is on a computer screen. And they are used to now working off the screen for trending data and that type stuff. But I came in right at…there was some transaction going on, and we still had some old analog type systems. But, it's primarily, like Neal said, high speed digital systems and systems keep getting better and better, and what that allows is less people to support the facility.

NW: We use, they have an acronym for the systems that we use around the facility they are called TRADAR. That's an acronym for Transient Analog Data Acquisition system. And what this is, is down in the test facility there was an instrument room down at the RETF facility, all the analog data was fed in to this system down there where it was digitized, formatted, and then it was transmitted up to the control room where it was put onto disk. And then the data would be transmitted as a file over to the central computer building which used to be the 10 x 10 office building, and then they built the RAC (Research Analysis Center) building which was building 142. And data would be fed there, and when they purchased the VAX Clusters from DEC Company, we used the DEC VAX Cluster computers for doing the number crunching, and then the data would be then transmitted back to the control room, where it could be analyzed. So the data went around the world.

DB: And the research engineers could modify test parameters. They would look at, tell us whether or not they hit the data point they were looking for. If they did, we could go on to the next data point. If they didn't, we could repeat the test, and all this turned around probably within 15 minutes. And within 15, 20 minutes, if we could set back up to fun another test firing. So it became really high speed and fairly accurate, and a really quick way of being able to get tests done.

NW: We would shoot for a data point, and if we missed the conditions, we would repeat the data point after analyzing the data, and if we made the data point, then we would move on to the next data point.

In the control room, during the test, would be the main ops engineer, a test conductor, plus anywhere from one to a dozen research engineers, plus generally one of the electrical...electronic ops engineers which is what Doug and I would do plus the technicians.

During the test, the control was given to the test ops engineer who ran the control console.

DB: The way a program normally worked is, for instance, starting from scratch, a researcher would come with the research requirements document to the operations group, and the operations mechanical side and operations electrical side, which is us, would get together, meet with the research engineer, go over his parameters, see what was realistic and what was not realistic, try to come up with unique ways of doing things. If he really needed to get some data, we would invent ways of being able to do the test so we could get the data. At which point, we would then build the facility up, and depending upon how complicated the program was, it could take anywhere from two months to three months to build a test program up down at the facility and also prepare the data system and all the instrumentation.

NW: Doug and I would design the data acquisitions systems, the instrumentation, the servo controls for controlling the propellants, the coolants. We were responsible for all that.

DB: The mechanical guy would be responsible for putting in any new systems. Sometimes a researcher would come in and we wouldn't have exactly the setup that he would need, so we would have to mechanically redesign the test cell. And the mechanical guys would size valves, size pipes, and tell us what they required, and we would have to put the control systems together to be able to do what was required for the operations engineer.

NW: We were actually responsible for the dynamics of the research facility. We had to, plus besides the instrumentation, data acquisition, controls, we had movies, pictures, we would take movies. We had FASTEX cameras for high speed video photography. We also had closed circuit TV systems that we were responsible for, plus lighting.

As far as during when the test conductor is at the console, and he hits the button on the console, that says "start," the computers will take over. And there was a big abort button also on the console. So there were two ways to abort. One would be if the test conductor saw something on his instruments or on the TV screens, he could abort, or there was a lot of automatic monitored conditions through the instrumentation computer systems that would monitor all critical parameters, and if they were out of condition at the time that they were supposed to be in that condition, the computers would automatically shut down the test run, and put us into the safe mode.

DB: Most of our tests when we ran rocket tests would last maybe two to three seconds at most. So there isn't a lot of reaction time for the person that's running the test. The ops engineer to be able to abort the test, normally once he pushed the "run" button which took the computers into action, the computers took over and they monitored parameters and would abort the test if something went out of whack. Occasionally, before they pushed the start button, they would bring pressure up to the valves and stuff. If they saw something leaking, they could abort the test that way. But most of the time, the computers did all of the aborting. And, then of course, after you abort, you have to figure out why you aborted, try to correct the problems, so that you don't abort again, and then try to get the data point you're after. And many a brainstorming session was going on when we would try to abort. And had we had an abort, we would try to figure out what was going on.

NW: Everyone pitched in. When there was an abort, we all would pitch in and try to solve the problem.

DB: I grew up in Brookpark which is just attached to the NASA facility here, being, growing up in the 60s, I watched the moon landing and everything else. So I was always fascinated by NASA, and of course at night we could hear NASA. We could hear the wind tunnels roaring across the airport to our house. So when they built this facility, the rocket engine test facility, it was pretty isolated. There wasn't a lot of houses in the area. Mostly farmland. As the community of Brookpark grew up, the houses started to infringe on the base. So when I arrived here at NASA in the 80s, the houses were pretty close, within a couple of miles to a mile of the facility. Maybe even as the crow flies, a little closer. And most of our tests were small. So when we tested, you couldn't really, the noise didn't carry too much. Even though the facility was in a ravine, it wasn't like it propagated very far. But later on, when I tested here, was here in the 90s, we brought a big engine back in, which is what they used to test in the old days. We had some hard starts, we call them, primarily it's when we get a little fuel rich, and the engine burps. And when the engine burps, like a 40,000 pound thrust engine burps, it does make a lot of noise. And we had neighbors calling in, they thought something had blown up at the airport, thought something had happened at NASA. And as a matter of fact, we shut down one time for a couple of weeks trying to eliminate the hard starts because we were getting quite a lot of phone calls. And one of my funny stories that I like to tell is one of our managers came in after we supposedly had solved the problems, and made the comment, okay, it's okay to test now. Whatever you do, do it quietly. And we all looked at each and we got a 40,000-pound thrust engine on the stand, and he's telling us to test it quietly. And we're like, okay, that might work. And lucky for us it did. We were able to get the test off. We didn't have any more hard starts, and we were a good neighbor. It's kind of funny because the facility was here first, and the people moved in, and they knew what they were moving into. But, it's just the way it is, so....

NW: In the 70s we were doing a lot of low cycle thermal fatigue studies on chambers, on materials for the inside of the rocket engine chambers. A lot this work had to do with the SSME[1] engines on the space shuttle. And what we would do is, we had a test article or test engine as we, on the test stand, and we would fire the engine and bring it up to thermal equilibrium and then shut it down. Because there is no, you don't gain anything more out of running it out. And we would shut it down, let it cool off, and ignite it again. We called this our low cycle thermal fatigue program. And we would do this run three, four nights a week. And we would fill up our run hydrogen tanks and pressurize, and we could get anywhere from 50 to 100 cycles out of the engine before we had to shut down to reload the run hydrogen tank. Well, it would sound like an awful, awful large steam engine chugging up a hill, because you would hear this boom, boom, boom. Well, thus drove the neighbors down on Cedar Point to the west of the back gate there crazy. And this used to bring a lot of complaints from some of the people back there with our testing at nighttime. Because we generally we would work

[1] SSME: Space Shuttle Main Engines. These are liquid oxygen/liquid hydrogen engines attached to the space shuttle orbiter.

all day. We were running the RETF facility two shifts a lot back in those days, and we would set up during the day and test in the evening. And it meant long hours for a lot of us. But, anyway, when we were testing, really moving, we would sometime go through three loads of hydrogen, and we were running maybe up to 250, 300 pulses in an evening. Well, the neighbors did not like that then. They used to call in to the fire station and the main gate, quite often complaining about us. And a few times we launched, as Doug alluded to the TRW program there, we launched rocket engine parts over the hillside, but never launched anything close to inhabited areas, but we did blow up the facility. The facility was designed to come apart. Where the rocket engine was, it was a structural steel frame with blow-out panels. They were plastic, fiberglass panels that they usually separated from the frame, and it would relieve the pressure. So when we blew up, sometimes these panels which lie around the courtyard, around the facility. And I was just thinking here as Doug was talking before of one incident that had happened. I can’t remember when it was, in the 60’s, late 60s, early 70s, and we had an explosion, a hard start, and they launched some of the parts of the engine across the little valley there into the woods there, and they sent some of the mechanics over there because they saw little fires, little hot parts of the engine glowing in the leaves. It was in the fall. And so a couple of the mechanics ran over there. Well, somebody called the fire department up, and they came down and they have their hoses there, and they saw across the creek bed there, they saw a red thing, and they started shooting their hose over there, and there was one of the mechanics had one of those big flashlights with red around the side, so when he was holding it up sideways, you would just see this red thing moving around, so they started shooting the hose at him.

DB: They soaked him.

NW: A little humor, 'til somebody yelled, you’re getting me wet, from across the creek bed.

GD: Can you talk about the importance to industry? (paraphrased)

NW: These are questions for the research people to answer. Quentmeyer and Hannum should have answered those for you. They were more involved with this end of it. Doug and I are mainly just involved with engineering the design of getting the tests done. And we’re really doing the engineering work down there. The concept comes to us, and we have to make it work. We have to get the data.

DB: Operations engineers, sometimes we get lost in the shuffle, but I think it’s one of the most important things on the lab. One of the things that we do is we take the research concept that is either from a research engineer here at NASA or out in industry, and who has gotten together with a NASA research person, and we take the concept that they have and we make it work. We do the actual nut-and-bolt engineering, along with the technical staff.

NW:

We actually take their ideas and we design the hardware, we have to make it work, we have to test it, we have to acquire all the data, and a lot of times we have to take the research engineers and tell them what they have there. We have to explain the data to them and point out to them what they actually have, why it didn't work, or why it did work. And we have to design the electrical systems, the mechanical operations engineers do the hardware, like George Repas. Doug and I did all the electrical work. We have to design any electrical control systems, we do the computer work. We program the computers that run the tests. The tests are all automated. Rocket Engine Test Facility is one of the first rocket facilities to use computers, and to actually automate the whole tests. The tests operations conductor just would push a button, and the computers take over and do everything for them. So we design all, we put the hardware together.

DB: We did the engineering.

NW: And also the instrumentation. We would design all the instrumentation.

DB:
There is actually something that operations engineers, Neal, in particular, sometimes unique instrumentation will be needed for a particular test....

[GD: do over]

DB: Sometimes our tests required special instrumentation and Neal did more of this than I ever did. But he worked with companies, and you can elaborate, with companies and actually designed certain pieces of instrumentation that would wind of being used in our test, and later on the company would then market as a marketable test, something like the PRTs that you designed.

NW: Back in the 60s and the 70s when we had more money in our budgets, and in the early days, a lot of times the manufacturers didn't have in their catalogs instrumentation that we needed, and so we had to design and try to coerce some of the manufacturers to build specialized instrumentation. And on a few occasions, they became catalog items. One of the ones like Doug was referring to was when we were doing all the combustion instability work back in the 60s and into the 70s, we needed some dynamic high pressure, high temperature pressure transducers that we could mount right on the rocket engine wall that could monitor these pressure oscillations that were occurring because of the liquid hydrogen. So there wasn't anything available. We worked with a lot of the companies. We had some money from the research people. We would go out to manufacturers and work with them, and we worked with Kistler Instrument Corporation in a spin-off, PCB Piezoelectronic [PCB Piezotronics] which is up in the Buffalo area. And we developed a piezoelectric[2] transducer that was water cooled. It

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[2] Piezoelectric: A material that generates an electric charge when deformed. Many crystalline materials exhibit piezoelectric behavior, including quartz. Piezoelectrics are used for cell phone and pager buzzers, spark generators, strain sensors in pressure gauges, and other applications. www.efund.com/materials/piezo/general_info

actually had a helium bleed which dumped helium right into the rocket engine chamber, and we could put these right on the wall of the rocket engine. And George would design bosses and we worked with, George and I worked on the design of these things together back in those days. George will probably talk about that this afternoon in his interview, and we developed these things, these transducers to where we were getting viable data out of them. And they would withstand, they were good for up to 3000, 4000 psi. We could run them up to 3000, 4000 degrees temperature. We developed rockide[3] coatings on them, and worked with the manufacturers. And they were a catalog item now though. Kistler MPCV (?) catalogs. They call them the rocket motor transducers. We also worked with Rosemont with PRT temperature sensors for emergent cryogenic temperatures. We needed the faster temperature censors in the cryogenic range because of the dynamic conditions. When you're testing the rocket engine, things happen awful fast. So we did some of the in-house work here with our instrument labs. And worked with developing more dynamic temperature censors using the Platinum Resistance Temperature, that's what a PRT stands for.

Doug and I both were involved with the TRW programs (with TRW Corporation). And it was a joint effort with McDonnell-Douglas, which is now part of Boeing, TRW and NASA. And it was called the Pintle Injector Program. And I think the basis for this was a term that we used to have back in the old days before Doug was at the lab, our chief, Bill Conrad come up with the concept of billing, what he called it a chief dumb booster, which we aren't allowed to use anymore. But this is what the Pintle injector was to actually evolve into. And they came to NASA and asked us to work with them. TRW built the engine, and we did all the testing at the Rocket Engine Test Facility.

DB: The funny thing about that is TRW went shopping around the country looking for a facility to do their testing in. And they came around, they went down to Marshall, and they went to a few other places, and they finally got in contact with some research engineers here, and we told them we could do the tests for X, whatever X was, I'm not sure what the dollar amount was. So the TRW people were intrigued by this. So they decided to come in and they wanted to meet the engineering staff. And I'll never forget this meeting. We walked into a room and it was Neal, myself, two mechanical operations engineers, George Repas, and I think one of our technicians, and the TRW contingent came in with about six people. And they were mostly the researchers, and they said, okay, where's the rest of your staff, the operations staff. We looked around at each other, and said, well this is it. And they totally went into shock, because they had been all over the country, and they had never seen a facility of this size having only four or five operations engineers. So they were a little leery of bringing their engine in here to test because they didn't know what kind of data we would give them. They didn't have an idea of what the capability of the facility was. And to be honest, there was some trepidation on our part. We hadn't tested an engine this size in quite a while, so we had to make sure the facility could hold up to the pressures that was going to make, the temperatures. So we had to do a lot of preliminary testing of our scrubber and of the facility to make sure that it would still be able to handle the heat and the

[3] Rockide: find out what this is from the HAER Documentation

pressure that was going to be developed by this engine. And when we were okay with the facility, and we were sure it was going to be all right, the okay was given that we could do the test. And Neal had to work quite a bit with their electronics guys.

NW: When they sent down their chief instrumentation supervisor and some of their engineers, they were still so leery of us, our capabilities, like Doug said they were in shock of the smallness of the crew running the facility. And just five of us, five engineers took care of the facility. Three test stands, A, B and C down there at the rocket engine test facility. So they wanted to bring in all their own computers, and instrumentation, and they, we worked with them and told them we didn't have to. But they still were leery, so they sent truckloads of equipment here, and we tried to work with it to mesh it in with our systems, and found out it was just too cumbersome, and their equipment wasn't compatible, if you might use that term. So we finally convinced them to let us go with our own systems, our own electronic systems and instrumentation systems. So with some reluctance, they backed off, and their equipment for the most part sat there. We've used a few of their electronics, but not very much, about 5% of what they sent. And the test went off, and things started rolling, and the data started coming...

DB: Great data started coming in.

NW: ...and they were elated, and Doug was here more than I was here.

DB: The data was really clean. They were really happy with it. Their people back in California were actually surprised at how good the data had come, and the test was conducted and pulled off, really on time, and on budget, and they were just elated, so they went away. We had heard rumors that there might be a follow-on program. We never were sure. Well about a year later they approached NASA, and they wanted to come back to RETF.

NW: Headquarters told them to go to Huntsville.

DB: Headquarters told them to go to Huntsville, and we will probably get in trouble for saying this, but it was political-type reasons.

NW: They didn't want to have anything to do with Huntsville.

DB: Mainly because they were very satisfied with the data they got here. So what they wound up doing...

NW: Be politically correct here...

DB: Well, I won't be. So they went to the congressional staff. This is the rumor we heard. There is no proof of this. But we heard that they went to the congressman for this area, put pressure on headquarters to allow them to come to NASA Lewis again, and they arrived back here with the follow-on program, which, we of course were elated. Most of the engineering staff, research operations were elated we got the test. And this time, it was funny though, instead of sending truckloads of equipment and busses of people, they sent one operations guy, one mechanic, one researcher.

NW: And many phone calls, and paperwork, and e-mail messages, but they just let Doug and I do everything. And they were just so happy. The reason, if we can say, the engineers from TRW told me off the cuff that they were so happy with what we had accomplished, that the tests, they accomplished all data points, above and beyond, the data was just fantastic. Everything was done on schedule or under schedule. When they had in prior programs gone down to Huntsville, they were distrustful of the people they worked with. Everything was over budget. Nothing was ever done on time. The schedules were blown out of the water. So they just kept insisting on coming back to work with us. And they were still amazed that we could do all this with such a small group of people. Jerry Starr (sp?) was the head instrumentation engineer and supervisor from Huntington Beach, and when they came up here he told me, he said, with this facility this size, we'd have 30 to 40 engineers. And he was still in shock. You couldn't believe it, we did it with five engineers.

DB: The rocket engine test facility...I was born in the 50s, but the rocket engine test facility was built in the late 50s. And one of the reasons that drove the facility to be built was that the United States of course was in a space race with the Russians, and we decided that we wanted to have a facility, we needed to have a facility to test high energy fuels and hydrogen being one of them. And there really wasn't a place anywhere in the country that was capable of doing that at the time. So they scouted around for a site and they picked Cleveland for several reasons. Number one, it was in an isolated area. The airport out here was by itself at the time. There was Wright-Patterson Air Force Base down in Dayton which was in control of the Air Force's hydrogen program and the space program from the Air Force's perspective. This was a NASA facility, so a NASA facility here which helped a lot. And there were some companies that were building some propellant capabilities where they could actually get hydrogen to test nearby. So RETF was proposed to be built here, and originally it was going to be a larger facility and it was scaled back. But still when it was completed, which was A stand, it was the largest high density propellant testing facility in the country. And later on it was surpassed by other facilities in other places. The capability of A stand was I think 50,000 pounds thrust.

NW: The facility was designed to run a rocket engine up to 50,000 pounds thrust.

DB: And in the beginning, it didn't have any engines quite that large, but they were of the larger size, mainly for hydrogen testing.

NW: The facility was also unique in the fact that it could handle storable propellants. It had what you might call a chemical treatment plant alongside where Doug mentioned the scrubber section, the rocket engine would fire into this big chamber with many, many spray bars in it. And they couldn't run what they called storables or dirty fuels, rocket engine fuels and test those. And the spray bars would wash out all the bad chemicals out of the discharge for the rocket engine, and put it into a big detention tank down along the creek bed there. Then they would have pumps, and they would pump this up into chemical treatment tanks, baths as they called them. And they could remove the nasty chemicals and the discharge the water that's left over back onto the creek already cleaned out. So it was a unique facility. It was a pressure-fed facility. It was not a pump-fed facility. And one of the of things that made it unique was the high pressures that, the facility was modified over the years, allowing it to run higher and higher pressures. And we had the capability to go up to 6000 psi with our gasses and which meant that taking into consideration pressure drops throughout the system to get to the rocket engine, we could actually run a rocket engine of 4000 psi which make it quite a unique facility. It could handle multiple fuels. We've tested hydrocarbons, hydrogen, UDMH[4], hydrazine fluorine and so it was a ubiquitous facility. And this is what made it unique. We were very good. Doug and I worked with the electronic and instrumentation systems and the Rocket Engine Test Facility, the B Stand came along in '84. A couple of years later the C Stand was built. Our supervisor said we want to be able to switch from one test stand to the other from day to day. And we looked at each other and said, oh my gosh, but we did it. We designed, redesigned everything and gave them that capability. So that they could run the A stand one day and the B stand the next day. Switch back to the A stand, go to the C stand.

DB: It became a mechanical problem to switch between stands, not electrical any more, so we were happy about that. The B Stand came along in the 80s. They were looking for a place to build a facility to check a high area ratio nozzles. Ten thirty to one area ratio. And some of the researchers can get into why they wanted to do that, the technical details. The bottom line is it's more miles per gallon is the way I like to look at it. If you can coat, what they wanted to do is confirm the CFD code.[5] They had certain convictions that were saying that this efficiency was what they would get out of this type of nozzle configuration. And they needed to prove out the data with data. So they built this facility to be able to do that. And it was an altitude facility. And we could pull down to a vacuum, I'm not sure, 100 torr we could get down to.

NW: We could simulate about 220,000 – 230,000 foot altitude. And to pump down, there again down to a tenth of a psi.

DB: And the facility worked really well. It accomplished what it was meant to do. They finished the final testing in 1993 on that stand for that particular test. Some other tests that were running there. As a matter of fact, when I first came on board in '86, they were actually testing a hydrazine thruster on the small little engine for space

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[4] UDMH: Unsymmetrical Dimethylhydrazine. This was reported to have been the storable liquid fuel of choice for rockets by the mid-1950s. It is used in virtually all storable liquid rocket engines (www.friends-partners.ru/partners/mwade/props/n204udmh.htm

[5] CFD Code: Computational Fluid Dynamics Code. Higher-level computer 3D modeling software used to predict flow velocities, chemical concentrations, pressure loss, and other data for objects (www.aerospaceweb.org/question/airfoils/q0035.shtml).

station in the upper thrusters and actually did get put on a space station and was used for their altitude adjustment rockets. Little tiny thing, I swear it was about that big.

NW: It was on mono propellant hydrazine powered thruster and they wanted to prove that this thing could be fired over 900,000 cycles. We tested it to over a million cycles on the facility. And they were just elated. They gave us this algorithm of firing sequence cycling in this thing that was unbelievable and we worked this thing out with our computers and got it to run. And they were just elated.

DB: That really showed the flexibility of the equipment that we had. Because like I mentioned before most rocket tests lasted two to three seconds. This was a life pulse test on a hydrazine thruster. The test was started 8:00, 9:00 in the morning and would run until 4:00, 5:00 at night non-stop. So our computer systems had to be set up to collect the data, keep collecting the data, and keep collecting the data so that we didn't overflow our disks. And you guys did a really good job on that. I was just coming on board. It was a fun project to start off on. And then the C stand was designed to be a seals tester. We never really ran a program down there unfortunately. The seals test rig (?) was designed, built. We started to do some preliminary tests on it, and the project funding dried up. We were having trouble with some of the hardware.

NW: We did have programs, but they were high speed, turbo pump, tests with seals and bearings for pumps for high pressure rocket engines. And the hardware was made by MTI? Well, the hardware failed. They would get up to around 80,000, 90,000 rpm, and then we had a rub. They wanted to test at 120,000 rpm, and the hardware, they could never get the hardware up to speed. They would have failure.

In the early days working at the rocket engine test facility, we were working in combustion instabilities and with the hydrogen engines, which meant higher temperatures, higher energies, higher pressures and we ran into this problem called combustion instability. So it became a big problem in developing rocket engines that were using liquid hydrogen as a fuel. So we had to come up with ways to monitor what was going on during the combustion process in the rocket engine. Well, we went up to industry and looked and there really wasn't anything in the catalogs or on the shelves that would fulfill our needs, so we had to reengineer, develop, work with manufacturers, give them seed money, and in the process we developed rocket engine transducers that are in the catalogs these days of Kistler Instrument and PCB that we helped developed here at the RETF facility and the main development was with the piezoelectric high frequency, high pressure, high temperature rocket engine that is called the rocket motor transducer in some of their catalogs. And we developed these in the late 60s and into the 70s. And what we can do with these transducers, we can mount them right on the rocket engine chamber wall. They are in a water-cooled jacket and we actually run those up to 1000 psi pressure on the inlet water and the helium, there is a helium bleed through an orifice that bleeds helium into the rocket engine chamber. The helium does not affect the combustion process at all. And that helium pressure had to be at 1.5 times the maximum pressure that was taking place inside the combustion chamber.

GD: [getting too technical]

NW:...We had to develop unique instrumentation that did not exist....
You want me to start over. - Well, when we got into working with the hydrogen rocket engines and the combustions instability, we went out and we found out that there were not instruments, transducers or instrumentation out in the marketplace that would satisfy our needs, so we had to develop, work with manufacturers and develop transducers that were unique at that time. And a lot of this instrumentation became standard catalog items with these manufacturers.