Oral History of Roy Applequist

Interviewed by:
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Jim Porter: We're here today to discuss some interesting development things which occurred to make the modern disk drive industry possible. We have with us today Roy Applequist who was a gentleman who made many of those things possible by getting them done, we have with us also Terry Johnson, who is an old colleague of Roy's over the years and can advise us on what some of those things were needed for and how they happened. And assisting me in doing the interviewing today, I'm Jim Porter, assisting me and with me will be Tom Gardner who will also be asking I think some usual feisty questions as we get into this subject. So to start, I'd like to ask Roy where did you come from Roy and how did you get started in the computer and disk drive industry?

Roy Applequist: Well, I started really work with General Electric as a tool and dye maker, went through an apprentice course there, and got up to manufacturing-engineering. Went off to World War Two for three years, came back to General Electric and continued with the manufacturing-engineering.

Terry Johnson: Roy, was that before you went to college, or after?

Applequist: This is before, I went to college after -- I spent a year at General Electric after I returned from the war, and decided that I might want to do engineering. I didn't really feel that I was of the quality in educational ability to --

Porter: So then where did you go to college?

Applequist: I went to college at the University of Alabama. We went down there because the colleges were so full at the time because so many veterans were going off to college, and I thought I would spend the first quarter or half at Alabama and try to get into a university closer to home, but I really fell in love with it.

Porter: What kind of a major did you have?

Applequist: Mechanical engineering.

Porter: Mechanical engineering, and graduated?

Applequist: In 1953.

Porter: That's the same year I graduated from college, but you'd had a head start with a lot of work before I did.

Applequist: <laughs> Yes I hired in at IBM, they came down to the university and interviewed people down there, and --

Porter: You say you started with IBM then in 1953?

Applequist: Yes, started in IBM in 1953. My brother had already hired in there six months earlier, and worked on the card machines, card punches, and the tape punches and readers.

Johnson: That's what you worked on, or your brother worked on?

Applequist: No, my brother, he was an electronic engineer, so he worked on secret programs there at IBM, and then I was --

Johnson: And the location of IBM that you were working in?

Applequist: That was Poughkeepsie in New York. That was an unbelievable place compared to General Electric, which is a ancient plant, it had oak floors, in the manufacturing facilities it was polished oak floors and so on, it was unbelievable. But anyways, I spent a year and a half, maybe two years there at IBM doing card punches.

Johnson: Do you remember one of the machines that was associated with?

Applequist: I think it was the old 24 I think, was the model number on the machines then. What we were doing is increasing the speed, these operations on these machines, and we start with changing the pulley diameters to see what happened. And so I enjoyed that work very much.

Porter: After the tab cards, what were you working on then?

Applequist: Well I left, I went to Lockheed, I wanted to come to California, my brother had come to California, and I wanted to come to California, also to escape my mother-in-law who was harassing us quite a bit.

Porter: Do you remember what year you went to Lockheed?

Applequist: It was 1955. But I got a job as a product engineer there at Lockheed, but I felt totally unqualified for that job. The machinery were two and three stories tall, and we were yanking stripped metals and doing all kinds of stuff which was way beyond anything I did at General Electric, I got myself a good (inaudible) there. And Lockheed, well, I did do a job at Lockheed that they really were happy with, to their surprise <laughs>.

Porter: You stayed there you said two years?

Applequist: I was there at Lockheed for two years.

Johnson: Actually at Lockheed you designed the flap mechanism for the Electra right?

Applequist: Yes, it was a big weight reduction and so they gave me the job, and it turned out that they were very happy with it and they decided they were going to do that also and the Constellation. But anyways, that was not my place, and --

Johnson: So in other words actually when you left IBM in Poughkeepsie, the reason why you left there is you really wanted to get to California with IBM and you thought that they apparently wouldn't transfer you. So when you got to Lockheed then you? --

Applequist: Yeah, I tried to -- but they were trying to get employees for IBM down there and so in the Los Angeles area, I saw the advertising and so I went to an interview, made out the application and so on and for --

Porter: For IBM?

Applequist: For IBM, and sat in a line for some time, because the interviewer was running behind schedule, and when I got up there, I had to go upstairs on the next floor and we got up there and sat down, he looked at my application and says “Oh, so what do we say, you worked for IBM before?” I said “Yes,” he says “Well, we don’t rehire,” and he threw my application in the wastepaper basket, and that I thought was the end of my career at IBM.

Porter: But you did actually go to IBM later didn't you?

Applequist: Yes, my father was working up here at 99 Notre Dame, and he put in a word for me, and so they agreed to interview me up at 99 Notre Dame. I missed the date that I was supposed to get there, so

the person that was to interview me wasn't there, but they got Don Johnson to interview me and he okayed my rehire, which I have never forgotten.

Porter: When did that happen then, what year?

Applequist: That was 1957, summer of 1957. So I came up here shortly after that and began work at Notre Dame, and my first job was they wanted to go to a single thickness on the Ramac, I guess that's the name, was it the Ramac?

Porter: That was the Ramac with a twenty-four inch disk.

Applequist: Yes a twenty-four inch disk and two disks were glued together, they wanted to be able to do a single disk, and so my job was to build a machine with a single disk and determine what kind of resonances and vibrations and run-outs--

Porter: Was it still a twenty-four inch disk or did it get smaller?

Applequist: Yes, yeah, no twenty-four inch, yeah all my work I did at that time was the two foot disk. And then when we found that the single disk would work fine, then they wanted to look at the possibility of having two actuators on the same base, and what we found with that was that if you're accessing in one the disks above and below the head and arm assembly would displace quite a bit, enough so that the next actuator the heads were ram the side of the disk if you were to access to those disks. So --

Porter: We probably should explain to anyone who's not familiar that an actuator is the device in the disk drive that moves the head back and forth on the disk.

Applequist: Yes, on that machine there was only two, a pair of heads and for twenty disks, so you would select the disks and then the carriage would carry those heads up to that disk and then they would enter the disk.

Tom Gardner: Roy, I'm curious, do you know why they had two disks originally glued together, and was the replacement the same thickness?

Applequist: No, all that had been done earlier, I think Don Johnson was the one that had been responsible for the coating and the disk configuration we had then. I had no knowledge of what he had done or anything, but I just sort of at that time that that's what I thought I knew.

Porter: So you started working at the 99 Notre Dame facility, or did you also go to the new factory which was built out on Cottle Road?

Applequist: No, it was 99 Notre Dame, I worked there for I think a year or so, because following that at that same location they wanted to do a all hydraulic version of that unit to get access times down and so on, so I worked for nine months on designing a hydraulic actuator that would do the vertical access to the disk and also drive the heads into the disk, to the track.

Porter: So was that used on the newer disk drive with twenty-four inch disks which had flying heads, the 1301?

Applequist: No, the hydraulic actuator went all the way into product tests and so on, but it was never, I don't think they never considered that for production, I think the cost of it would've been too high, and whatever the reasons were, but it would've been a high cost, it was a very complex machine, it was fun to work on. And things I've thought about later would've probably made that more feasible than what they had, because they had to pump 400psi constantly, which just generated a lot of heat, so I had to find a way to drop down in pressure like we did on the 1311.

Porter: I might mention the 1311 came along a few years later and that was the first disk drive to go down to fourteen inch disks, and it uses a disk pack which was removable.

Applequist: Yes, that was a concept that Jack Harker had suggested as a low cpst drive, that you'd have that the disks that you could take off and store and put back so you can increase the data capacity storage by just taking, you know, which is like tape or something, you could just remove the disks.

Porter: And, of course, that disk drive set the model as a fourteen inch removable disk pack rack for the rest of the decade of the 1960s.

Applequist: Yes, well that came -- I don't know how they arrived at the fourteen inch or something, yeah, generally it's because they die out or the thickness and whatever that was available commercially we didn't try to come up with a higher road, it was whatever you could buy more or less.

Porter: So we did a separate oral history with Jack Harker and crew on the beginning of the 1311, and he had some interesting stories on that point, yes.

Applequist: Yes, well now that part of it I knew nothing about, but on the 1311 after I quit work on the hydraulic unit and I went into some kind of product testing or something that now was assigned to Jack Harker.

Johnson: In other words, after the Ramac assignment you went to work for Jack Harker?

Applequist: Yes, directly after that, and because of my hydraulic experience there I think that that was decided ahead of time that that hydraulics was going to be used on the 1311, and a low cost drive. And so I was a good candidate for that to have come up with that other one which would make a hydromatic example. <laughs>. And so the first 1311, in order to keep the cost down and everything, they had a return to zero concept, so they would always start from zero, so I built a hydraulic unit that would do that job, it would go back to zero and then go out to the track, so they always started with a zero. And that possibly could've been because of a problem with Potter who had patented the down count system where he could down count to zero, then you could start from any place.

Porter: Potter was the other company on Long Island, Potter Instruments?

Applequist: I'm not sure where they were, I know --

Porter: They were out of Long Island. That was Potter Instruments.

Applequist: Was it, anyways there was a lot of anger there, that we'd had to do stupid things because of this simple, simple concept, and so that --

Johnson: To avoid their patents you had to do all these work-arounds in other words.

Applequist: Yeah, so that's probably why that was returned to zero concept on the very first unit we built, and I made the layout that -- there wasn't very many of us on that program, at least in the mechanics of it. There was myself and there was I think two designers or draftsmen or so on, so it was you could do almost anything you wanted. So we completed that. I remember doing the head loading mechanism, out of the meetings would come “Oh we want to be able to unload, if we decide during a load cycle that we didn't want to finish this load cycle we could abort,” and I had all these different things. Anyways, I couldn't see why they needed that and I didn't know how to do that, so I went back to a concept that came from my army experiences, and our thirty caliber machine gun, had a mechanism for re-cocking and so that was a starting point for the --

Porter: An interesting concept to borrow.

Applequist: Yeah, I borrowed that concept.

Porter: So after that era, what did you work on then?

Gardner: Excuse me, but --

Porter: Go ahead.

Gardner: Roy, would you explain what “return to zero” means for those who might not?

Applequist: Well you have the track zero, which was the furthermost track, the largest diameter track in the pack, and that would be track zero, and they could have guard bands outside of that but when that track is track zero and the carriage would drive back to that, so wherever it was it would go back and restart from that same starting point.

Johnson: So did I understand, did you actually do the head load mechanism that was used in the 1311?

Applequist: Yes.

Johnson: So not only did you do the head load mechanism but then you also did the hydraulics that was used in the 1311?

Applequist: Yes, and the spindle, and a gear and rack.

Johnson: Wow, and a gear and a rack.

Applequist: Yeah, so although there was there, Russ Bruner I believe is the one that worked on the original kind of pipe model of something, and they started I think with purchased hydraulic parts and so on and I put a gear and rack, so on, was a base concept kind of a model. But I did the gear and rack and that the gear and rack were meshed, were pressure meshed together, which I didn't for sure know we were going to have problems with that or whatever, so there was a lot of work done to make sure that that concept was going to be all right. So it was like one of the wheels of the carriage was the gear and rack interface.

Johnson: So that basically the hydraulics got you to the general area you wanted to get to, and then the gear and rack did the final positioning.

Applequist: Well the gear and rack came, that was you had a rotating gear down at the base plate that would position, that the rotational position of the gear and rack, and that was the precision for that whole mechanism there was in that gear and rack, much as today they do in the calipers you can buy, the little calipers instead of the micrometers, they now have the calipers that read out the dimensions fairly accurately. And that concept was used in that carriage.

Porter: Going on then, what did you work on after the 1311?

Gardner: One more question if you don't mind, that was a separate detent that then detented on the --

Applequist: Yes, yes, the detenting on that mechanism was also hydraulic, came from the same -- aligned from the same hydraulic unit that would control the detent also, and it was just a plain purchase gear that the detent would go into and so there was a lot of precision already in the purchased parts, you could buy very high precision gears. So and a heavy carriage was made so that the accuracy of positioning on every track was measured, and I think there was down at three-tenths of a mil or something, you know, very close so that you couldn't get anything away in trying to precision the heads, so the temperature and these things were all taking their share of off-track, giving the off-track and so we didn't want to give away any. So that arrangement of the gear and rack by even measuring the run-out of the ball bearings and marking the high spot of the ball bearing, the run-out of the cut gear on the spherical shaft that engaged the rack, the run-out of that was marked and then they were assembled with these mark points, that to get every bit of tolerance out of it we could. And I know going down on the line because they couldn't get the carriages through this measurement that all they found that they had marked at the other part of the ball bearing, the low run-out rather than its high, so that was enough to throw this where they couldn't get it through.

Gardner: Was the pall of the detent a triangle, did you wedge --

Applequist: No, no it was wedged then, the teeth on the gears made to engage a vertical tooth in a rack, so it has a curve to it, and all the things you want to get good detenting position, of a detent into a curved part so you don't have to worry about how accurate the base of the detent is and so on. So, and then we tried to get all the run-out we could out of the spindle so we decided that the only way to do that was to grind the spindle after the spindle was assembled, and that was a lot of hassle with that, manufacturing did not want to do that. And Joe Southorn then was the one that came then and said "Are you sure we can do this?" so we had to do it ourselves and show them yes, that we could do that. You couldn't even touch the spindle or it would move, or more than that tolerance, so we finally did it. But I think that continued to be an argument for a year or two after it got out to Rochester where they were making them.

Porter: But you made it work?

Applequist: Yeah, they worked.

Johnson: And the historical significance of this is that same actuator that was used in the 1311 was used in the 2311 and then the 2314 which spanned many years of production of disk drives, so. And the actuator carried on through that, so it was a very significant benchmark in the history of disk drives. And I'm sure Jim could probably maybe, or Tom could talk about what the span of the 1311 to the 2314 was in years.

Porter: Well the 2311 and the 2314 were really parallel in many ways, the 2311 came out first, and then the 2314 actually shipped I believe in '65, along with System 360, and the two became very widely used, I think the 2314 was the most widely used disk drive in the Sixties because the IBM System 360 came to dominate the whole high end computer industry.

Johnson: So the number of years between the 1311 shipment and the 2314, the end of its deal, how many years was that?

Applequist: A couple of years.

Gardner: At least eight, maybe nine.

Johnson: I mean the total years that spanned between.

Gardner: At least eight, maybe nine.

Johnson: So the 1311 and to the end of the 2314?**Tom Gardner:** We don't exactly know when the 2314 ended, probably '70 or '71. Course the 3330 didn't ship until '72.

Porter: '71.

Gardner: Was it '71?

Porter: Yeah.

Gardner: And the --

Johnson: That total number of years would've been from the time of the 1311 to the more or less through the 2314, how many years the disk drive?

Gardner: Yeah, the problem is IBM --

Porter: It's about eight years.

Johnson: About eight years.

Gardner: Oh it's more than that, I think.

Porter: No, eight years, the 1311 shipped I believe in ’62.

Gardner: So well ’62 to ’72 is ten.

Applequist: The 1311 --

Porter: Shipped in ’62.

Applequist: ’62, it was a long time getting it into manufacturing, and we shipped one that was a double ten disk unit to somebody, and I didn't know what that was all, but I thought it was an oil company or something, and they got one which we didn't let the, not me, but the company didn't want the customer to realize that we were going to do a interchangeable, so the pack was bolted onto the spindle.

Johnson: What year was that, Roy?

Applequist: I'm not sure, I would've thought --

Porter: Actually, nevertheless, the removable disk pack became the dominant standard throughout that decade, and a term which you don’t hear too much in the computer industry anymore was very dominant then, “Save and Restore.” the idea that you could take an application off the computer by removing the disk pack, putting another application on with the disk pack, so that one in a company for example, you could update all the employee record and information and then you could take that disk pack off and do another project, you could put the disk pack then on at the end of the week and do the payroll and all the data would be there. And that term was called “Save and Restore,” all made possible by the removable

disk pack which made it possible to have more applications used on a computer than otherwise would've been possible.

Applequist: Yes.

Gardner: To probably further answer your question Terry, the problem was, of course, IBM had a lot of 2314s come off rent in the Seventies as the PCM started, so you really don't know exactly when they stopped building new ones 'cause they were remanufacturing. But if you count remanufactured 2319s I think those shipped until '74, so you could easily come up with twelve years of shipment of products counting the remanufactured 2319s in the Seventies, that'd be '62 for the 1311, some time in '73 or '74 for the last 2319.

Johnson: Great, the point being is that this particular actuator and did the head load mechanism, I don't know if that stayed the same, but anyway Roy was kind of a fundamental creator of something that lasted a very large span of the disk drive industry and that's just kind of a point.

Porter: That's the key point and that development work had one heck of an impact on the storage and the industry in that decade. So let me ask that earlier question, after the 1311, what did you work on mostly at that point?

Applequist: Well, I probably did some work with the 2311 'cause there were some changes that were made.

Porter: And doubled the capacity?

Applequist: Yeah, doubled the capacity. The original unit though that we designed for the low cost drive was a ten disk drive, it had the big pack, and --

Porter: The 1311 actually had six disks.

Applequist: Yes.

Porter: And then when they went to the 2311 they went up to eleven disks, in fact.

Applequist: Yes, but we started with eleven disk packs, so the machine was designed for eleven disk packs. So then towards the end of that program when it was decided that they only needed the six disks,

they wanted to go to a smaller pack because I think they had a system going where they would go four times the capacity each time on a new product, so that made that possible for the next product now they could go four times. So we just took those heads out, left everything the same, took those heads out, and so there was almost no design work necessary to do that. And then when we got to the 20 -- I think it was the 2311, and they went back to the eleven disks --

Porter: With the 2314?

Applequist: 2314, yes, then they only had to put the spots in the existing T block with the new spots in for the new heads, so there was very little work to do. And in the CE lectures there, one lecturer there commented how we had lucked out <laughs>, but it was we had lucked out in a way that we didn't -- because we were going to six disks that we redid the unit for that, but then everything was all there. I mean maybe it looked a little silly, the 1311 could've looked a little silly because, you know, high T block and all that stuff.

Johnson: One of those situations where you made the right decision for all the wrong reasons right?

Applequist: Yes <laughs>.

Porter: Okay, but then the 2314 comes out, becomes very successful, and by the way, the 2311 and 2314 were the pathfinders for a whole lot of other companies that copied IBM's concepts, and became the so-called "plug compatible drive makers," Control Data, Century Data, ISS, the twelve guys who left IBM that were known within IBM as "the dirty dozen," who started ISS, and then Potter and Marshall. And Memorex was the first of the plug compatible drive makers. All those companies then made drives compatible with the IBM drive, so they used the same disk packs for the 6 high for 2311 and then the 11 high pack, the 2316 pack, and the 2314, so what you did created a wave of followers in the industry, and out of that came much of the modern disk drive industry by the way. So after all of that you did all the fine tuning to make the 2311 possible and then the 2314, what happened next?

Applequist: Well, I began to work on the 3330 I think then, it was the servo drive.

Porter: But you had IBM's code name of Merlin right?

Applequist: Merlin, yes.

Porter: Yeah.

Applequist: Yeah, so I began work on that, and then we had that one was going to be voice coil drive, the 1311, or the 2311 was going to be voice coil, too, and I was near panic on that, because I knew they were going to carry a new basket full of stuff and say “Here's your new actuator.” And so I worked out, did some changes in the hydraulic unit and got the access time down to what they wanted as another speed to the unit, and so that made it --

Johnson: Do you remember what that access time was?

Applequist: I believe it was average of eighty-five milliseconds I believe, in that area.

Johnson: And what was the original 1311 access time, do you remember?

Applequist: I don't know, it would've been a little bit more, maybe 15 milliseconds more or something, because if you didn't drill a full stroke when you got up to top speed then the unit would slow down to the detent velocity well short of where it wanted to go, so then it would have to travel two inches a second for a number of tracks before it reached it.

Gardner: Was the velocity controlled or was it an open loop just by the flow?

Applequist: No, it was just a four solenoid cell in there that told this thing what to do, and one was of course the full speed and then a interim speed and a low speed and a detent.

Gardner: So the more fluid through the piston the faster it went?

Applequist: Pardon?

Gardner: The solenoids increased the flow of --

Applequist: No, it would not do anything to it except go, so you could say and then it would go up to a velocity which was determined by the pump output.

Gardner: Okay.

Porter: And it should be noted that the voice coil actuator you're working with still would kind of go in and out, straight in and out.

Applequist: Yes.

Johnson: Yeah, but we're still talking hydraulics right now, and it was like, you know, I understand they were talking about putting a voice coil actuator in a 2311 and you…

Applequist: Somebody was working on --

Johnson: The access time of the hydraulics so that they stayed with the hydraulics there, which they also stayed with in the 2314.

Applequist: Yeah.

Johnson: And it wasn't until the 3330 project you started to work on it that you began to work on again a voice coil actuator.

Applequist: Yeah, I was a hydraulic bigot up until the 3330 or Merlin.

Porter: So the 3330 development went on for quite a number of years didn't it, before it was actually shipped in 1971?

Applequist: Oh, yes.

Johnson: Do you remember what year it was that you started working on a voice coil for the 3330?

Applequist: I would say it would be ’64, or maybe ’64, possibly ’65 start, but…

Porter: Six or seven years in development?

Applequist: Yeah, something like that, we started with the voice coil, because there had been some voice coil work going on, so there was a big -- a lot of large magnets laying around, and I think it, and I'm not sure of that, but I think that the hope was that the 2314 or whatever it was, the drive after the 1311, maybe it was the 2314 then, yeah --

Porter: Should we mention I think the 2314 took the capacity up to twenty-nine megabytes per disk pack, and then as you went up to the 3330 actually the capacity increased to one hundred megabytes per disk pack.

Applequist: Yes, but it was done with the capabilities of positioning the head, the accuracy you could position the head, where you could go from twenty mil tracks to ten mil and then later it eventually got down to five mil track spacing. So that was the limiting thing, I mean they could go higher bit density and so on, but there was the track positioning accuracy. And to get really good track positioning you had to serve a hundred pack to get rid of temperature growth of the disks and this type of thing.

Johnson: And so that was basically the reason why you needed to go to a voice coil actuator?

Applequist: Yeah, you had to serve a -- you couldn't serve it with a hydraulic unit at all. So and there had been work going on on bigger voice coil motors with that work had been done, but so there were a magnetizer, a magnetizer was available, magnets were laying around different configurations and sizes, so we started with building some kind of a voice coil motor that we could put on modified carriage parts that were available on the machines that were in production.

Porter: But it did go into production and the 3330 became a major product, too.

Applequist: Yes, but that was the beginning work was how to get a voice coil attached to the actuator and replace the hydraulic unit, that was essentially the first.

Porter: Let's hold it there for the moment. We need to change this tape.

Porter: Let’s continue with the things you did on that 3330 program. Before you left IBM and you went on to another company, what was involved in the other projects in getting that 3330 program ready?

Applequist: Well, one of the major ones was we had to get rid of the old -- I had to get rid of the head load mechanism, because it didn’t -- it wouldn’t allow a good design for the carriage. And so the design problems, trying to use the torsion rod mechanism that was on the other drives, made it something I didn’t even think I was going to be able to do. So I had to find another way to do that, and I came up with the concept that maybe just unload the heads with a cam. And so I tried to sell that at IBM, and we did just a few heads. So -- and it did look like it would be okay to do it that way and --.

Johnson: Another way of saying that is you used a ramp loading, as opposed to…?

Applequist: Oh it's a ramp unload. They say ramp loading but it's -- really camming those heads off of the disk. So it's a cam unload.

Gardner: Fixed cam moving ramp.

Applequist: Yes.

Gardner: So as the head goes forward it slides down the ramp.

Applequist: Yes.

Gardner: To load.

Applequist: Yes.

Gardner: As the had comes back it moves up the ramp, on the cam.

Applequist: Yes. Yes, essentially as the head comes back to just beyond, the head tracks zero, and this cam goes and lifts up the head so it could come on off the disk.

Johnson: So were you key in suggesting that system, Roy? Was that the --?

Applequist: Yes, I did it, and I tried to sell it first and hoped somebody might want a patent or something. And then- because I had a lot of work to do with the carriage and the motor and so on. So I still had the time elements involved and so I thought, get somebody else to do that, try that out and see if it would work. But I just couldn't; nobody was interested in that. And then so I did some testing and so on, enough to the point where we knew it was going to work, or thought it was going to work.

Johnson: And which once again became a standard of the disk drive industry, because this cam loading became the way that heads were loaded on a disk- loaded and then off loaded, off load the disk, until much later in the disk drive industry when with the Winchester technology they found out they could- they determined a way that they could land the heads on the disk. But once again this was a fundamental state of the art which was used for many, many years until basically you didn't need to lift heads off the disk anymore. So once again Roy was key in a very, very pivotal point of the industry which became a standard of architecture.

Gardner: I'd elaborate on that, that even today in mobile disks where you can't leave the head on a disk, they still unload with a cam ram approach. So even to this day…

Johnson: Right.

Gardner: …20, 30% of the market still uses the same technology.

Applequist: That's such an obvious concept though that IBM didn't think it was patentable.

Porter: Well I can give you a little remark on that. Years later a company in Colorado that developed the 1.8 inch drives did do some work on ramp loading and did get a patent on that concept, and IBM then later went into a cross licensing program with that company, to get full rights to that ramp loading technology.

Applequist: Oh, really?

Porter: So that you were the preliminator -- you did the preliminary work on a lot of the stuff that came along later and actually was patented by somebody else then.

Applequist: Yes. Well in the beginning patents were not important. You're there first and got the market and got there first, and then the other people would have to try to copy what you'd done, if they want to do it.

Porter: That's significant. Now anything else in the early work on the 3330, before we go on?

Applequist: No. Primarily it was a carriage and it had the loading mechanism. And that was the thing that was really different.

Porter Okay. So you then left IBM. Why did you leave and where did you go?

Applequist: Well I left IBM. I think I was getting tired of --. Number one, they were building a building out in the parking lot that didn't have windows in it; it had slots or something; and I could see -- I thought I saw the future out there; and they had stopped the travel to shows and things like that. So you were getting more- it felt like it was enclosed, you were not open to the world.

Porter: So why did you select Memorex?

Applequist: Well that came because of Cliff Akers, a friend of mine who had gone off to college to get an advanced degree, had worked at IBM, and I knew him at IBM and he was just a kid. But we got -- because he had to come to me quite a bit about -- because he was in Product Engineering he had to ask questions about different things. So I got to know him. And then he went off to college and then he came back and tried to get back in IBM. And he was walking around in our area there. So I saw him and I says- I greeted him and I asked him, "Well what's going on out there?" And he says, "You would be surprised." And so he suggested to Bob Brumbaugh, who was a man at Peripheral Systems, that he could use me for- he could try to get me to come in there.

Porter: Peripheral Systems, a subsidiary that Memorex had set up to do disk drive development.

Applequist: Yes, they set up a deal where they would advance money for development of some product. I don't think it was a disk drive but it was some product. And they -- it evolved into a disk pack, or disk drive, and they got to where they thought they had something, that was saleable- which they didn't. They didn't realize they didn't but –

Porter: I should comment that I went to work for Memorex in '68. I managed product management on disk packs, on computer tape, during that era, in a different part of the company from where you were involved. But Memorex was the hottest thing going in the valley in that era and it attracted a very, very active group of very ambitious people- quick, bright. And it was the, as I say, the hottest thing going in the valley at that point in time. So you picked a very interesting company to go to work for.

Applequist: Yes.

Gardner: Roy, the rumor I had heard was that Memorex was working on a key to disk system- that was the original charter.

Applequist: Yes, because there was a company that was doing a tape to--.

Gardner: Key to tape.

Applequist: Yes. Their idea was, well, we'll use a disk.

Gardner: And the further rumor I had heard was that they approached IBM to buy 2311's, and the IBM salesman said, yes, $27,000.00.

Applequist: Yes, $26,000.

Gardner: 26- okay.

Applequist: Yes.

Gardner: So we heard the same rumor.

Applequist: Yes.

Gardner: And that they said, “Well, we want to buy a hundred.” And the salesman said, “Fine, that’s $26,000.00 times a hundred. The price is the same.” And that led either Brumbaugh…

Applequist: Yes.

Gardner: …or somebody to say, “Gee, this is a better business”; because I think the cost of a 2311 was about $1700.00.

Applequist: Yes.

Gardner: So IBM was selling for $26,000.00.

Applequist: Well any good manufacturing engineer could go through that and see a lot of profit. The hydraulic unit was $89.00, the disk was- the spindle was $40.00. And they could go out to the centers and get these costs, because some of that was just farmed out.

Gardner: Larry Spitters doesn’t acknowledge that rumor, but I’d heard that, also.

Applequist: Yes.

Porter; And it might be mentioned that Memorex did become the first company to ship a 2311 equivalent product, and I believe they actually shipped it -- they said they were going to do it in ‘67; they actually did it in ’68; and then by the end of ’68 or early ’69 they’re actually shipping a 2314 equivalent product also, that would use the same disk packs that IBM used, even though there might have been some differences in controllers and so forth. So you picked the innovator of -- the first copier of IBM, let’s put it that way.

Roy Applequist: Yes.

Johnson: So when you actually went there though they had no disk drives in production. Is that --? That was the case at that time.

Applequist: I don't think they did yet, no.

Porter: They didn't.

Applequist: No, no. So they were just sort of in the beginning of --.

Johnson: You might explain that when they originally wanted you to go in there, I think they wanted you to do a hydraulic actually -- right?

Applequist: Yes. Well they were looking for somebody that could do the hydraulics. And Cliff Akers, he knew that I was the only one on the hydraulics at IBM on that unit. It was a problem for my manager that any question that came up, they could call me off. But fortunately there wasn't a whole lot of problems with it, except once out in Michigan they had problems there; I had to go out there.

Porter: But they did go to a voice coil actuator -- right?

Applequist: Pardon.

Porter: A voice coil actuator was what they went to.

Applequist: Yes. Well I first suggested before -- I didn't tell him, Bob Brumbaugh; I just told him that there was better ways to do it than a hydraulic unit. I says it's like with the airplane where they --. You want to design a piston type engine for an airplane. Now he says -- and everybody else is doing jet engines. So I says I wouldn't work -- I told him I wouldn't work on a hydraulic unit. And so he says, "You're not going to have to"- he made that promise to me. And so I joined up. And he stuck to his word, absolutely, to the point where even though I was worried about the success of the company, he wouldn't let me do anything, in the hydraulic area. But Memorex -- but there was a lot of internal problems because of that, that they had the group, the sales group and so on, that convinced them they had an operating unit and they just had to clean it up and then they would have a market for it. And there, Bob Brumbaugh is going off on a tangent. They had already ordered much of the machinery that was going to be used for manufacturing on their design. So they had all these machines; some were already in, some were on order. And so a very big part of their budget was already spent. And so it was Bob Brumbaugh that saved that.

Johnson: Basically it was your voice coil actuator that Memorex ultimately ended up shipping, rather than the hydraulic action.

Applequist: Yes, they never got that right.

Johnson: So you were kind of the back room effort…

Applequist: Yes.

Johnson: …that replaced this thing, that they didn't politically dare talk about.

Applequist: Yes.

Johnson: That it actually ended up to be the thing that they shipped was a voice coil actuator that you did for Memorex.

Gardner: I think Roy actually did a lot more than the voice coil. We have a picture here of -- from your patent.

Applequist: Yes.

Gardner: Of the mechanism. But I think the rack and detent was probably your design.

Applequist: Yes, yes.

Gardner: The differential transformer.

Applequist: Yes.

Gardner: The carriage?

Applequist: Yes.

Gardner: The weight.

Applequist: Yes, well all of the mechanics; there was nobody else for the mechanics -- yes.

Gardner: You basically did all the mechanics…

Applequist: Yes.

Gardner: For the Memorex 630, 660.

Applequist: Yes. Well it was an easy design, I thought; in fact, it could be almost done on yellow paper. A lot of it was just done on yellow paper. I could make a layout and then I could just put the drawings -- pull the drawings, parts out, and put it on yellow paper and --.

Porter: But did you have difficulty getting agreement to do what you wanted to do?

Applequist: Pardon?

Porter: Did you have difficulty getting the management of that group to agree to --?

Applequist: Well I would have; except for Bob Brumbaugh it would have been not done, it would not have been done. But he stuck to his word, right to the point where --. But we would give a little bit on that. But that's right. And even the Board of Directors was not allowed into the lab area where I was. Cliff was at one end, I was at the other, and it was a lab, and the marketing people were not allowed in there, at all. They were just absolutely not allowed in there, because of that -- I think of the emotional feelings that were going on.

Gardner: Terry says your voice coil was elegant compared to the one that IBM shipped -- four years later?

Applequist: Yes, that was part of --. I went to the depositions on that and they pushed on that, pushed and pushed on it, and I told them, the voice coil actuator is a very simple device. And I said that the fact that -- I mentioned the fact that -- because they'd let me see the 3330, and I had these big metal, iron parts that- to deflect the blocks, and so on.

<Crew talk>

Johnson: I think that one of the interesting things is that the IBM 3330 motor used a very, very high flex density gap in the coil and in order to implement that, it turned out that they had to put a great big shield in front of the motor, because the flux was leaking from there out, and actually magnet -- and erasing the data on the disk. And Roy's motor at Memorex was about- probably 40% the size of the IBM motor and required no shield or anything because he used a totally different concept of basically of -- in the design of the motor. So one of the interesting things about Roy's designs often is that he, rather than kind of going through the mountain, he figured a way to go around the mountain, sort of thing, and very, very fundamental concepts which made the thing much, much simpler.

Applequist: Well it simplified the velocity transducer problem, because we could have a single transducer in the center of the motor, connect to the carriage and get a good signal out. But IBM's was -- they required two transducers and then they're not on the center of gravity anymore then because there's two of them. So they had to put two coils in there; one is just used to cancel out the noise from the motor. But we used shunts or- in the motor itself to reduce the flux; that would affect the --.

Porter So you were working on the motors used with the Memorex equivalent to IBM's 2311, 2314? Then you also worked at Memorex up to the point where they were developing the drive to be equivalent to IBM's 3330, weren't you?

Applequist: Yes, I -- Well the other two, the 630 and the 660 were using some of the technology that was necessary on the 3330.

Porter Which came later -- yes.

Applequist: Which came later and which IBM was working on at that time. They were using the voice coil concept and they decided to go with the cam unload head. So that primarily was the difference is any type of carriage that would go with the voice coil. That was essentially all there is to talk about in the mechanics.

Gardner: Well Roy, where did the differential transformer come from, the one that senses the rack?

Applequist: Oh yes, I did that, too.

Gardner: That's where you and I first met.

Applequist: Oh, is that right?

Gardner: I did the circuit for that, I fixed the circuit for that.

Applequist: Oh, yes, and the one for detecting the sectors in the pack.

Gardner: Yes.

Applequist: Yes; I mean you could get electrocuted with the output valve. But yes. All right, so yes, those two, being able to detect track position, without having a rotating disk that would tell you where you were. We had to go directly to looking at the rack.

Gardner: Roy had two transformers at 1½ times the track -- the teeth pitch.

Applequist: Yes.

Gardner: So, because the transformers were separated by half a track, you could then differentially look at the output.

Porter: Now which project was this?

Gardner: This is the 630 and the 660.

Porter The equivalent to IBM 2311 and 2314.

Applequist: Yes.

Gardner: Right. And because the accuracy was in the rack, you had an incredible precision – actually --

Applequist: Well, except for the offsets that you get in the transducer.

Gardner: Yes.

Johnson: So one of the interesting things is it sounds like that Roy had designed the mechanisms that were used in the 2311 and 2314, but when he went to Memorex basically he moved the voice coil

technology into products which competed with the products which he had originally developed for IBM. So he basically moved the technology forward at Memorex into what would not be seen at IBM until the 3330 came out. But in a way Memorex at that time had had a high- an advanced version of the 2311, 2314, which Roy was key in developing, and that technology flowed into- it basically flowed into the 3330 at IBM but it flowed into also the 3330 competitive product at Memorex. So it was interesting where he actually obsoleted his own technology and what he did at Memorex; in other words he obsoleted the technology that he'd used at IBM.

Gardner: Well I understand Memorex licensed Willy Jilke and Pertec on the Memorex mechanics. Do you recall anything of that?

Applequist: No, that's the first I heard that.

Gardner: Okay.

Applequist: No, that's the first. But I know that there was -- Jilke, whatever was happened there, that he'd get ahold of their drawings in the hope that -- he was going to buy 300 drives, the mechanics for 300 drives. And they were going to do -- We had to give them all of the parameters so they could do the circuits for it. But somehow they ended up with getting drawings or something; they were making other parts themselves, as far as I could see. So Bob Brumbaugh took one part into me once and he says, "Do you recognize this?" And that was one of our parts. But that's as far as he went. I just agreed, yes, that's our part.

Gardner: I have one follow-up on that. My understanding -- back to the transformer and the rack -- is that that design then was used by CalComp, in a track following mode; that is, the output of the transducer and the rack was good enough to servo on, so they could close the loop on your design, which is something Memorex never did; but that was CalComp's basic -- Jilke taking that from Pertec to CalComp, but I've --. That's sort of again rumors I've heard and I don't know --.

Applequist: Yes, well -- I heard, too, that they were servoing on that transducer, yes.

Gardner: Yes, so it gives you an idea of the precision; even though Memorex always detented, Roy's design was capable --. And then of course CalComp did a double density 2314 using servo, which Memorex was never capable of because it stuck to the rack detent system.

Johnson: One of the things that became important when you went from the situation where basically it was an open loop system, with all these drives that were detenting to the base plate, well when you came to the 3330 well then the whole concept was that you would write a track on the disk and that way you

would be able to follow the run-out of the disk and basically get much greater positioning accuracy because now you were following the literal track that was on the disk. So basically a very key issue that began at this point also was the pack writer to write the servotracks on the disk that became the reference from that point on that wherever that disk went on a spindle or something, or it had different run out or whatever. So why don't you talk a little bit about what you did with pack writers, which were the forerunner, the really key forerunner to this particular technology which basically the 3330 became that level of technology. So why don't you talk a little bit about what you did with pack writers?

Applequist: The problem --. There was something with the pack writer that IBM had a lot of problems with. It became an inter-divisional project or something. And so I think it was holding up the release of the machine or something. Anyways, well we had to have these packs before even IBM had them. And we thought --. So we built very simple pack writers; it was built on a piece of granite, four inches thick, two feet by three feet, and everything was on it; everything was very solid. And I don't remember all that was going on there. But I remember we were trying to write the tracks and we thought the heads would have that same old five degree angle that would get the heads, because it had two elements on the head; as you had to have the head at an angle because the tracks, because of the radius around the spindle center; the heads were made at like approximately a five degree angle. But we had to write several tracks which were -- the bits were on each track; it was really in line, they were really in line. You wrote a set of prints on one track and then the next track all of those bits were written in the center of the other tracks, or on the other center of the other bits. And so we had to --. You might have been involved in that Don.

Johnson: In other words there was an inter-leaving situation where the bits on one track were here and the bits on the next track were inter-leaved in there. So they had to be precisely --.

Applequist: Yes, it had to be very precise.

Porter: Okay. That situation resolved.

Johnson: Well, just a minute more. One of the things that --. If you look back at the history of pack writers, it turns out Roy was very fundamental in moving this technology forward. It turned out that IBM had used it; they were using a laser interferometer to position this mechanism and everything. And Roy, once again, went to a very, very simple positioning mechanism, which was a rack and pinion thing, where basically it was an extremely simple sort of a mechanism; no lasers, no interferometers or anything. But one of the things that Roy did is he aligned up the mechanics so that it turned out that IBM had used the interferometer out here at the side. So they were very, very accurately measuring what was happening over here. It was a poor indication of the accuracy of where the heads really were, and Roy, just by geometrically designing it correctly, was able to use a very low technology rack and pinion thing which wrote beautiful packs. And fundamentally not only did he do this for -- basically for what we did at Memorex but I think actually Dysan as well. He designed the pack writer that Dysan -- which became a

large manufacturer of this sort of thing. But anyway, once again, a fundamental step forward in the technology of -- was required for this 3330 class of products, and once again done in a very, extremely simple, straightforward way that was kind of a signature of Roy's designs.

Gardner: How did you get the bits to line up? How did you get the transitions to line up?

Applequist: Well they -- IBM had screwed the head around; so I had a zero twist. So they just went in a straight line. It had to be that --. I'm not to --. I can't remember exactly what all the reasons -- but when you have two elements, an erase element and a write element, that they had to be in line on the track. And it must be that they went down to a single element or something. I don't remember what that --. It was all simple enough at the time.

Gardner: The last question on Memorex that I have is Peripheral Systems Corp. was an entrepreneurial subsidiary. Peripheral Systems Corp., you joined, was a Memorex entrepreneurial subsidiary.

Applequist: Yes, they advanced the money.

Gardner: Tell me about working in an entrepreneurial subsidiary.

Applequist: Well I left IBM, secure with all kinds of health benefits and a pension and all that, and then I went over there; and within a week I began to realize I had taken a pay cut to work there. And I did have some stock that I bought at a dollar a share or something. And I had already been playing in stocks, so I knew that that probably was- could have been worthless paper. And so I became very nervous, a little bit about that. But it was the best thing I did.

Gardner: The stock didn't turn out to be worthless, did it?

Applequist: No it didn't.

Porter: So why did you leave?

Applequist: Why did I leave? Well, we already discussed it a little bit about --.

Johnson: You're talking about leaving Memorex now.

Porter: Leaving Memorex.

Applequist: Oh, leaving Memorex. Well we had built the pack writer, several writers for Memorex, and that was a real winner and we put out five packs an hour, one operator, and it was ridiculous prices they were getting for it. So that one machine, it could keep a company going. So and then Norm Dion asked me to come with him and I told him no, I didn't want to do that.

Johnson: And Norm Dion had sort of -- Dysan Corporation --.

Applequist: Yes, that was when he was trying to get the Dysan Corporation funded. And I didn't go with him, but I did agree to do a pack writer for him. But I --.

Johnson: This was after you left Memorex?

Applequist: Yes, this was after --. Well no, it was during the time that Norm was thinking about leaving.

Johnson; Oh, I see.

Applequist: And so on. So it was all -- it's all in the same time basis here. And then this Ivan Pejcha, who was working at ISS -- I think it was ISS -- they had this big concept of having four drives and four packs and so on, that he had sold -- he sold that to Storage Technology, I think.

Johnson: In other words, four spindles --.

Applequist: Four spindles.

Porter: Okay let's give people who we're talking to an idea. This is a brochure from Storage Technology. You mentioned that the operation that you got involved with is eventually sold to Storage Technology; I believe they had funded it in the first place, hadn't they -- the new operation when you left Memorex.

Applequist: When I left Memorex, for Storage --? You mean --?

Porter The Super Disk.

Applequist: Super Disk, no that was a Storage Technology --.

Porter: Exactly. So Storage Technology was the one that eventually put it in production.

Applequist: Yes.

Porter And the Super Disk -- if you hold this so it can be shown in the video -- the Super Disk consisted of 14 inch disks.

Applequist: Yes.

Porter: Four stacks of them, and the head positioning system was in the middle, of all of this.

Applequist: Yes.

Porter: And you were a key person in development of all of this, weren't you?

Applequist: Yes, I was. There were two mechanical engineers on it; there was Morehouse --.

Johnson: Jim Morehouse, yes.

Applequist: Jim Morehouse, and he was doing analytical work, and that was just up his alley, and he had some other concepts that we needed to align the heads and so on.

Porter: A couple of key points on this. This went to in effect a fixed disk situation, not removable packs.

Applequist: Yes.

Porter: And the head positioning system, the actuators, were not the linear actuators, moving in a straight line, but the head positioning system in the middle of this device used a rotary positioning system, which was a new idea. So it had some new ideas. Were you responsible for introducing those ideas?

Applequist: Yes. Well, how to do them, how to accomplish that mechanically. I think these -- what they wanted to do, they had an idea already, of what --. They wanted four packs and be able to access all the heads on one pack, on all four packs; they would all be on the same track and so on.

Porter: But you're using the word "packs"; they weren't removable packs, they were fixed disks in the stack.

Applequist: Yes, 20 --. 20 disks.

Johnson: Well it turns out that they had 64 disks split up into four spindles and so basically you had 64 --. Four spindles, 64 disk total, 128 heads, accessed by one deal. And it was an 800 megabyte disk drive which was basically -- they called it Super Disk because there was no other drive in the world at that time that had that kind of capacity.

Porter: So it was developed by you fellows there in the San Francisco Bay area, here in the Peninsula.

Applequist: Yes.

Johnson: Well the name of the company was Disk Systems Corporation which was funded by --. Basically Ivan Pejcha sold this concept to Storage Technology and Storage Technology wanted to get into the disk drive business -- that had been in the tape drive business -- and so they funded a startup which was -- the name of that was Disk Systems Corporation which basically --. The way they funded it is it had kind of a downstream, shotgun marriage arrangement so that if we reached certain goals, then they would exchange this Disk System stock for Storage Technology stock. And Ivan Pejcha basically had had --. Basically the fundamental concept that he'd sold to Storage Technology, and Roy came in and basically transferred what was supposed to be a carriage made out of a solid ingot of aluminum, machined out of one thing, well he did it in a way that --.

Applequist: It was a simple enough concept, but getting there was --. You think about it, that these halves had to be a mil in position from the center because -- so they would have -- as you went in an arc, that they would all travel the same distance, so that if you went out further on a radius, it would go further. So here you got a pack with -- you had four packs, and four heads out there. The center of these heads had to be within a mil. around --. The tracks on the pack had to be all identical, every track had to be identical to each other. So you had to do a --. And then you had to be able to adjust this stuff, in the machine. So the mechanics --. And not only that but the disks were the same as the disks that were used on the 3330. They weren't plated, they weren't lubricated or smoothed, and were not -- where they used the floating head, the normal floating head on them. And it turned out that the IBM head for the- was going to be the Winchester head or something on, that we took, and that was made out of a magnetic material which was very soft. So we thought all the time we were doing design work, we would -- when people were producing these super disks, these lubricated disks and the IBM had and all that, we would have -- we'd just use them. Well it turned out that they didn't work. I mean, there was an immediate crash.

Porter So you used the 3330 type disk?

Applequist: We had to design a ceramic head. It was brand new, different than IBM. It had the same size dimensions as far as the overall lengths and everything, but it was a brand new head; had to design a new head, able to land on a old copper disk and so on. So we had to do that. That just came up.

Johnson: Whereas the 3330 cammed the heads off of the disk before the disk was stopped, these heads actually landed on the disk and so they could not use a 3330 head on the Super Disk situation. So they had to come to a completely different slider material.

Applequist: Yes.

Porter: Well the production development continued on. You had the thing almost ready to produce, then Storage Technology took over and moved the whole operation to Colorado.

Applequist: Yes.

Porter: And it actually went into production there, and the Super Disk, under the STC name, first shipped then in 1975 -- right?

Applequist: I don't know.

Porter; I believe it did, yes.

Applequist: Yes, I --.

Johnson: Yes.

Porter: So the question then, you ended up not moving to Colorado, did you?

Applequist: No, I didn't go to Colorado, and there was --. I don't know, I thought that they really disliked me a lot and I got some very emotional conversations with them -- I forget who he was. But they had no idea what they had there; the people in Boulder had no idea what that machine was.

Porter: Okay, but you yourself went on to do other things. You provided consulting assistance for other people, including in the floppy drive area. You became an investor and a member of the Board of Directors of various companies.

Applequist: Yes.

Porter: But you never actually were on the payroll of another company after that point, were you?

Applequist: No, I helped --. I became part owner of General Disk which just did pack work.

Johnson: Pack writers.

Applequist: Pack writers.

Johnson: That's right.

Applequist: That was --. But meanwhile --.

Johnson: And you consulted with Dysan basically --.

Applequist: Yes, I consulted with Dysan and --.

Johnson: I remember Roy telling the story that he consulted with them on doing a pack writer -- right?

Applequist: Yes, I did a pack writer for them.

Johnson: And they didn't have any money, Norm Dion didn't have any money at that time, and so they gave Roy stock instead, see. And Roy, at the time, I remember him telling me that he thought that maybe this wouldn't even make good wallpaper. Well it turned out that it made very good --.

Porter: Well we've finished your actual experience with the companies, and we're almost at the end of this particular tape.

Porter: Okay, let's continue this session, now that we have a new tape to work with. Picking up from where we actually discussed this yesterday, and we were in the middle of the discussion of the Super Disk. And it's marvelous organization with those four stacks of drives with a rotary actuator in the middle, and we were just getting to the point of discussing that rotary actuator in the middle, which accessed the appropriate locations on all four of those stacks of disks. I guess the obvious question I would have was, "Gee, was this concept in place when you started work on it, Roy? And how did you implement this? How did you make this thing happen?

Applequist: The basic idea, I think, came from something circling in ISS. And Ivan Patia took the concept and sold it to Storage Technology. And then Ivan came to me after he sold the concept, he came to me and asked me to join the group.

Porter: It must've been quite a challenge to put this into actual life, since it had never been done before.

Applequist: Well, there was more to it than what it looked like to start with, because all the tracks on the four disk packs had to match precisely. So as the unit -- as the actuator rotated, it would be in the same position on the same track on all four packs. So it was a lot of mechanical thought going into how we could do that. Write the tracks, so that all the tracks were that precise that you could light up on one pack, and also have the other three heads precisely on that same track. So that even the pack writer had to be thought about and try to get every pack to be so identical.

Porter: It must've been rather interesting since no one had ever done the working model of this rotary actuator. What were the principal problems you found in putting it together?

Applequist: Well, almost every part of it that, even getting a motor strong -- powerful enough to rotate this unit that it took regular coil size wire. So we had to wind all the individual sections on this motor, so it could carry the current. Printed circuit wouldn't do it. We had to have regular sized wire, wind the coils, and then bond all this together into an armature, or whatever you call it, rotating.

Johnson: Just to reiterate here, you know, what was involved was this devise had basically 64 heads -- or 64 disks, and 128 heads, and it was basically designed to store 800 MB, which for that time was the largest disk drive, I believe, that had ever been conceived. So you know, the interesting thing about I this is what flowed out of this was one of the earliest rotary actuators. And it turned out in the end the way Roy had implemented it with the inertia of this, the actual moving inertia of this rotary actuator was such that it didn't actually take any more power to control this actuator than it did a normal 3330 actuator. So I mean, what came out of this was some of the fundamental things, which, later on in the industry to turn out to be the advantages of rotary actuators, which became the key technology later on in the disk drive industry.

Gardner: Just to clarify, Terry, the 3330 had 19 heads, and you guys were moving 128 heads with the same power.

Applequist: And with one circuit. That one circuit was shared by all four disk packs.

Gardner: Was the motor on the bottom of the stack? Or was the motor...

Applequist: Yeah, the motor was down on the bottom, you couldn't see it. You couldn't see that. It was all assembled, and it was unassembled with a turn of heavy wire around each magnet, and then it could be all magnetized.

Porter: How long did it take from the time you started on that rotary actuator, until you had good working models? A year or more?

Applequist: Yeah, it was about, I think probably...

Johnson: It was about a two-year development cycle we went through. And you know, almost everything had to be done, in the sense that there'd never really been anything done like this before.

Applequist: Yeah, everything in that, the disk was not -- we were looking ahead at what IBM was going to be coming out with, which was a Winchester head, and the disk that would go with that, a special disk that had lubrication, and so on. And when we got to that point where we were putting the disks in and getting the heads, we found that what IBM had wouldn't work on this unit at all. So we had to then design a new head, which was ceramic, and much more capable of landing on a rough surface.

Porter: Well, it was quite an exercise. Anything else to discuss on the rotary actuator at this point? I'm sure you put in some long, long days on that one to make that happen.

Applequist: Well, yes, but I think that's the only one that I tried to do for this, or even...

Johnson: Well, you know, it suffered the problem of -- there's this old expression in engineering of "Keep it simple, stupid," and it violated that rule in spades. But once again, the interesting things is it was one of the first rotary actuators, and it kind of in a way, what we then maybe didn't realize it at the time, but it foretold the way to do. And it wasn't that in the future they were going to move 128 heads, but you had to move much more rapid access times and everything. And that the rotary actuator basically became kind of the fundamental tool of the disk drive industry. And so it was kind of an interesting beginning.

Applequist: But the appearance of this huge drive, which had a hurricane wind involved with it. You didn't know whether you wanted to walk up to it or not.

Johnson: And it probably weighed, I'm not sure exactly, but I suspect it weighed about 500 pounds. Today if you think back, 800 MB for that day was a monstrous product. But when you think of 800 MB weighing 500 pounds today -- <laughs> and that was without a controller, that was just the drive, you know. So…

Porter: Well, we've come a long way. But of course, when you had your work substantially done, Storage Technology, which had funded the company then took over, I guess. And moved the actual operation to Colorado for production. And of course, as I realize, you didn't go along with that. You became a California guy, huh?

Applequist: Well, my children lived there, and they were living with my ex-wife. So she wasn't going to move to Colorado. And I started with General Disk, which was another company, and that was a very nice running company. And so I just didn't want to go to Colorado.

Porter: So what did you spend your time on at that point in the industry.

Applequist: Well, I think that the next...

Johnson: General Disk, they did servo writers, right?

Applequist: Yeah, General Disk, servo writers. There was three of us that did that. That was a very good job. I mean, it was the right product at the right time. We were doing -- well, everybody was starting to do servos. And we would do their packs, whatever the pack was, whatever the servo tracks were. We were ready to do it for them.

Johnson: Who were some of your customers at General Disk, Roy?

Applequist: I know it was that close.

Johnson: Oh, DEC? DEC in Colorado Springs, yeah.

Applequist: Yeah, that was one of the big data machines they wanted. And then we were doing the companies that were trying to do IBM compatibles. So we had a machine that would write these specs. I

did one for Dyson, and so that was many -- that was like -- there was a company, I forget the name, it's gone now -- but they ordered 11 machines over the phone, and they were over $100,000 each. And there was three of us.

Porter: So how long did you stay with General Systems?

Gardner: General Disk.

Porter: General Disk, excuse me.

Applequist: That was probably till 1980.

Porter: Till 1980.

Applequist: Or possibly a little bit after we sold our -- we sold the our ownership to the founder, sold it back to him.

Porter: And then what did you do in the industry?

Applequist: Then I think...

Johnson: When did you do the Tandon thing? You might've even done that while you were at General Disk, correct?

Applequist: Oh, I was working with several companies at one time, and at Tandon, he would come up to San Jose, occasionally.

Johnson: You're talking about Jugi Tandon, who ran Tandon Magnetics down in Orange County, yeah. LA area, actually.

Applequist: So whenever he was up, we'd have dinner or lunch or something and talk to each other. And he came up and he was sort of excited about the double-sided floppy he was selling to Century Data, was it?

Gardner: I'm told one of his very earliest customers was Tandy Corporation in Dallas, for the whole drive. He was making heads earlier, but then he moved into the drive business, and Tandy was one of his first customers.

Applequist: But he sold the head, single-sided head arrangement, he sold that assembly, and then the other company would finish the drive. And so he had a very good business going. Then IBM came up with a double-sided, and so he thought that he wanted to get a crew together and be able to manufacture the new head arrangement. And I told him that I wasn't interested in copying something from IBM.

Gardner: Wasn't interested in copying anything from IBM.

Applequist: Yeah. So then the conversation, he was pushing me to get involved with it. And then I thought, "Well, let's see if maybe we can do it a different way." And so that's we did.

Porter: So that project got completed.

Gardner: Can you tell us a little bit about the IBM way, and the Roy Applequist way?

Applequist: Oh, yeah. IBM had a very complex system. And they loaded both heads with a solenoid, the top head and the bottom. And then they had to float on a disk, so it was nothing that was keeping the disk in any one position. Both heads were trying to ride on a -- I pictured it like a flag in a wind. <laughs> And the old method was a button-head on the bottom. And it had a top arm with a felt pad on it that came down and pushed the disk against the button head. So what felt pad was the head, that I could do the job that the felt pad was doing. Well, it turned out that that did work out. I had to reshape the head, different things like that, but it did work. It was too stupid an idea. So IBM planned it. They had tried it, and it wouldn't work or something, because it was too obvious a way to do it. But it worked out that in the end I think IBM had to get out of the business. And the very last part was when Japan, there was seven companies in Japan doing it that way. And Shugart was paying royalties, but the Japanese companies didn't want to pay royalties. So there was lot of lawsuits and so-on involved in that. But it was very successful for Tandon.

Johnson: And it became an industry standard.

Applequist: That became the standard then. But the Japanese did a beautiful job of getting it into a little cartridge. And the one that we all know, and it went for years, I think as one standard that you could just buy that floppy cartridge, and a number of companies were making compatible drives for it. So that became a standard.

Johnson: I think something that's interesting in passing is that Roy, although he appeared on the patent for this, never was compensated for that at all. That's kind of an interesting thing.

Applequist: Oh, I had sent in all these depositions.

Johnson: And never was compensated at all. You know, it was kind of an interesting thing that not everything you do in the world...

Applequist: The thing is it was all done up in San Jose, and this other company that I was involved with. All of the work that was done -- we used our designer there in that company, you know, charge Tandon a fee for its design work and stuff. But I had the ports made with our (inaudible) shop that we used, and so it was all done up in San Jose. All the drawings were up in San Jose, and everything. So I think it was a problem during the time of the depositions that they had to go up to San Jose to get...

Johnson: This was when there was some litigation between Tandon and other companies that were trying to copy that. And you know.

Applequist: Yeah, there was seven Japanese companies who were doing it.

Gardner: For what it's worth, its patent is US Patent 4151573. And I think Roy's design -- I know Roy's design was adopted by everybody making double-sided heads. Shugart Associates, IBM took a license. And Tandon Magnetics sued in the international trade commission the Japanese companies who were importing drives, infringing Roy's patent, and got a very, very lucrative settlement from the Japanese companies coming out of the trade commission litigation.

Porter: Well, Roy made a very substantial contribution to Jugi Tandon's success with Tandon Magnetics, then.

Applequist: Yeah. <laughs>

Porter: They were a successful company.

Applequist: That was a fun job.

Porter: Yeah.

Johnson: Even though you didn't get compensated for it.

Applequist: <laughs>

Johnson: You gotta enjoy every day, right?

Porter: After that adventure, what happened next in your career?

Applequist: I think you and I went down to a show.

Johnson: Yeah, it turns out that just to pick it up, that at about that time that Al Shugart had formed Seagate, and basically they had announced the ST506 product.

Porter: The first 5-1/4 inch hard drive.

Johnson: The first 5-1/4 inch disk drive. And at that time I'd left Storage Technology, and I had contacted Roy and we -- I was looking for something to do, or a company to start, so we ended up going to the computer conference that year that was in -- which was about -- what was it? That was 1980, which was in Anaheim. And basically, Roy and I went down there, and then actually ended up going to the suite that Seagate had where they were announcing basically the ST506. And it turned out that Al Shugart had been fairly gracious in this. I told him that we were gonna try to start a company. He told me to "break a leg." And it turned out that Roy's involved became that they had announced a 5MB drive, and we needed to do something more than that if we were gonna be in that business. And so we were interested in doing a 10MB drive, and Roy basically, participated in the implementation of that. Maybe you could talk about what you did there, Roy.

Porter: And eventually became a director of that company you set up.

Applequist: So-called director. But I was more of a spy for (inaudible). <laughter> But the Seagate drive there was -- they were using a split-band. That was kind of a thing where like we were just with IBM. Whoever the lead guy, the lead company's doing, that if you're going to do it, you should try to work around that. But the problem with the split band is number one is it took a very special seal, or it'd fail and fatigue. And the other is stepper motor, it only could do about a three-quarters of a turn. So all your tracks had -- steps for your track had to be within this three-quarter of a turn of this motor. So, and gear and rack was -- I had years and years of gear and tracks, so while we would do a gear and rack, and a little gear on a stepper motor, so it could use that stepper motor now for a number of steps. It could go multiple revolutions on that motor if you wanted to. So it made it much easier to get any track density you

wanted. It could use even the same motor, the same stepper motor. And so then the rack and the gear was mated in such a way that it was like a roller on a carriage. So it actually positioned the carriage horizontally, like a roller on a way.

Johnson: And not only did Roy set up the initial architecture of the Miniscribe drives, but it turned out that we had gone off for -- Roy had gone back to California, and we'd gone off on our own and started to implement this. And then he came out to visit us again, and pointed out basically, but very diplomatically, I might point out, the way we had implemented it that the play in the bearings and everything would actually turn out to be an off-track thing. So we would have to control our bearing tolerances very, very tightly in order to implement it the way we had. And so he suggested a re-configuration of it where the play in the bearings on the ways of the carriage, would only be a second order of fact, which I attribute to having made the product successful. And you know, I attribute the fact that MiniScribe was able to be successful to not only Roy's initial concept, but his putting us back on the tracks when we off on our own had kind of got under way. And once again, this relates to a patent that Tom has there that was key to the MiniScribe's success.

Gardner: Could you zoom on it?

Porter: So how long did it take from the time that you fellows saw that ST506 and that suite in Anaheim, California, until you're actually in production at MiniScribe?

Johnson: You know, I don't remember the specific.

Porter: A year or two?

Johnson: I think it was about a year, or something like that. And once again, this enabled us to do something that was not a copy of what had been done before. A very, very simple concept, and yet, you know, once again, I attribute Roy's contribution basically as being one of the key success points of this area.

Applequist: It wasn't a full-time job for me. Colorado was 1,200 miles to my home.

Porter: As, I guess should be pointed out in that 5-1/4 inch drive field, from that first introduction by the company which became Seagate in 1980, two years later there were 30 companies that had announced 5-1/4 hard disk drives. So the ability to actually get in production with a cost-effective product apparently turned out to be something that made MiniScribe really possible.

Johnson: Basically, I attribute the success of the corporation basically to his mechanical design and John Squire's contribution. So fundamentally there's kind of an expression that I think in starting companies it's kind of the Olympics of capitalism and you can't be just good. You gotta be the best. And I think, and Roy's contribution, we got an element of that. In John Squire's we had another element of that.

Applequist: Had a manufacturing engineer, Glade Bagnell.

Johnson: Yeah, that's true.

Porter: What was that name?

Applequist: You have to have a good manufacturing engineer, it's absolutely a must.

Gardner: Did you mention somebody's name?

Applequist: Glade Bagnell.

Gardner: Pardon?

Johnson: Glade Bagnell.

Gardner: Glade Bagnell?

Johnson: Bagnell.

Porter: Bagnell. Thank you. Very good. Anything else with your adventures with MiniScribe as a commuter from California?

Applequist: Well, Terry put me on the directors there, and so I had to buy a suit and all that kind of stuff. <laughter>

Porter: Very good. And from there, with having designed a very successful 5-1/4 inch hard disk drive at MiniScribe, did you get on to other things, including smaller drives?

Applequist: No, not that I remember.

Johnson: I think that basically, Roy's one of these people that I like to think that, he always talks about getting the first sheet of yellow paper right. And once you get the architecture of a product, you know, sound, then you can -- it's all kind of downhill from there. But if you don't get that initial sheet of yellow paper right, then you know. And one of the things that Roy went on to do, precision scale, and various other contributions which are not directly in the disk drive industry, but he always seemed to bring, you know, whether it was designing the first motor for a rotary actuator that'd never been seen before, he always brought kind of basic concepts to the fore that became fundamentally sound. At any rate, that's been his great contribution in many, many areas.

Porter: Certainly not just an engineer, but an innovator.

Johnson: Well, you know, it used to be that Roy, we'd bring him in, and we'd say, "Roy, we've got this little problem over in this quarter in the machine." And he'd spend a day with us, and then we'd go to dinner that evening. And I said, "Well, what do you think about that, Roy?" And Roy would say, "Well, I think what you need to do is over here." You know, he thought outside the box, and where we had focused on one little area over here, he might say that the whole configuration, you know, the problem could be avoided by going to a different concept. And I think that this was kind of an example in his career in many, many areas, whether it was designing a voice coil motor for Memorex, equivalent of the 3330, which he did in a much compact, you know, very, very, you know, much smaller like, maybe 40 percent of the size of the motor that the IBM had used, and didn't require a shield. You know, I mean, these fundamental things were Roy. They used to say about him, "Oh, his calculations were kind of in the margin of his notebook," you know, and he avoided this frontal assault like drilling through the rock-face of the mountain. And he would find some pass around it where he didn't have to go through that. So that was kind of the characteristic, I guess.

Applequist: Well, basically it had to be simple so I could understand it.

Porter: Well, to perhaps wind up at this point, Roy, what -- as you look back on your adventures, and all this design work on disk drives, I think you said once before, you were having fun. Was that a good summary of what you were doing all that time?

Applequist: I was having fun.

Porter: You were enjoying it, as well as making...

Applequist: Apparently, I never got any pay along the way, it was only what the results would be. And so it was fun. And you had to be with the right group of people. I mean, you don't have that, so you always got to have your eye on who you were working with.

Porter: Well, as you put it out in our discussion a few times, you decided from time to time it was time to leave that group and move on. <laughter> And to enjoy the work is a key part of your background. I can see that.

Applequist: Yeah. And so I mean, I couldn't imagine going into this business today. It is just beyond comprehension to me. So I'm glad I'm retired.

Porter: Well, I think the industry is very thankful for your contributions. And I'd like to thank you, Roy, and Terry, and Tom for very interesting contributions to this discussion. Thank you very much.

Applequist: Thank you.

Gardner: Our pleasure!

END OF INTERVIEW

