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Interviewee: An Wang
Interviewer: Richard R. Mertz
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MERTZ:

The following is an interview conducted with Dr. An Wang, W-a-n-g in Tewksbury, Massachusetts, at the offices of Wang Laboratories, Inc. on the 29th of October, 1970. The interviewer is Dr. Richard Mertz.

Dr. Wang, would you care to describe your early training and education?

WANG:

I see. I was graduated in 1940 at Chiao-Tung University in China, and then I came here in 1945 and got my masters and PhD at Harvard.

MERTZ:

I see. During the war years, were you —

WANG:

During the war years, between 1940 and 1945, I was working for the Chinese Government, working on the — inside the blockaded zone, fighting Japan. And since we were technologically trained, we were working, rather than in the front line, working in the factory in designing and building radio receivers and transmitters for military use.

MERTZ:

This was back in Inland China?

WANG:

Inland China, in Kueilin and Chungking.

MERTZ:

Oh, I see. The college was in Shanghai?

WANG:

In Shanghai. After graduation I stayed one year as a teaching assistant and [went] to England.

MERTZ:

I see. Did you major in a particular field?

WANG:

Majored in electrical engineering, communication engineering.

MERTZ:

I see - rather than power?

WANG:

Rather than power, yes. Communication. Radios - at that time radio was a major part of communication engineering.

MERTZ:

Had you been interested in radio before in the sense that you had built one?

WANG:

Oh yes, even in high school, I remember at high school, I started building my own radio phonoset. That's in 1933 or so.

MERTZ:

Was it a crystal set?

WANG:

A crystal set.

MERTZ:

I see.

WANG:

And a very early version of vacuum tubes.

MERTZ:

Mhm. And this was a hobby that you then developed later?

WANG:

A hobby, yes.

MERTZ:

Now I understand from talking to other graduates of the college that this was an occupied - well, Shanghai was occupied. I understand, and the college was in the International Zone?

WANG:

No, that's in the International Zone for the year, but I just left in 1941, after I got one year as teaching assistant, in the summer of 1941 just a few months before, before the Pearl Harbor, so I just managed to go through Hong Kong, go to the Inland.

MERTZ:

So then you went Inland, I see. During the war years then you worked in the —

WANG:

In government - sponsored plants designing and building military receivers and transmitters.

MERTZ:

I see. And then this continued on until 1945?

WANG:

Until '45. And I came here, left in April 1945, and got here in June '45, just before the war ended.

MERTZ:

I see. And you came as a student?

WANG:

Went right into Harvard starting in September.

MERTZ:

I was wondering if there was any particular reason why you went to Harvard as distinct from any other school?

WANG:

Oh, well, at the time I think I just happened to. I heard about Harvard, so I applied, and they happened to, to just accept me. At that time Harvard was supposed to be the most well-known in radio, in electronic radio engineering, under Professor Chaffee.

MERTZ:

I see. And so then you were recommended by some of your former teachers?

WANG:

No, at that time, during the war-time when I got here, I stayed in Washington waiting to either go to school or go to another electronics plant, but right at that particular time school was easier to get in, while a plant was uncertain at that time.

MERTZ:

I see. So there was a choice of going into industry or going to school?

WANG:

That's right, or go to school for further study.

MERTZ:

And you went to Harvard and enrolled in electrical engineering?

WANG:

Enrolled in the so-called communications engineering at that time. Later I changed to engineering physics and applied science.

MERTZ:

With whom did you work then?

WANG:

First I got my masters degree just taking courses. I got my degree the next year in '46. And then, coming out I worked for a few months, and came back to Harvard in February of 1947.

MERTZ:

Did you specialize in a particular field in your masters work?

WANG:

My masters was just general communication engineering.

MERTZ:

I see. At that time did you know about, or were, you interested in computational problems?

WANG:

No, at that time I didn't know about computation. It hadn't been established at that time at Harvard. And, so - and even my PhD program, which I started in February [1947] graduating in June 1948 was specialization using nonlinear systems, my PhD thesis under Chaffee, Professor Chaffee. That studied nonlinear effects, which was very useful later. At that time I was not even involved with the computer. But I got a job. Just before graduation I interviewed at the Computation Lab, they requested research fellows. So I applied and I got accepted, approved, provided I graduated, got my PhD. So I did, so I joined them right after graduation.

MERTZ:

Did you work for industry for a while between your masters and PhD?

WANG:

Between masters - I think I worked in industry for a little while in New York, I think — yea, for a few months and then went to Canada working for the Chinese Government which is in area a few months, three months, and then I came right back.

MERTZ:

And this is in connection with electronics?

WANG:

Yes, in connection with purchasing of electronic equipment.

MERTZ:

I see. Then you decided to —

WANG:

To continue studying.

MERTZ:

continue studying. Was there any particular reason why you decided to go on?

WANG:

I felt this was a better way and then I got — I wrote to Professor Chaffee if he had any way that could support me any way and then he found a teaching fellowship for me at Harvard. Coming back as a part-time teaching fellow at the research department and then worked on my PhD program.

MERTZ:

When you originally came to Washington, had there been a possibility of going into industry?

WANG:

The Chinese Government at that time had a program to supply me about $150 a month.

MERTZ:

I see. In other words then you were under government sponsorship.

WANG:

Under government sponsorship.

MERTZ:

I see. So that the economic part of this was a consideration getting a grant to continue your studies?

WANG:

That's right.

MERTZ:

It was important.

WANG:

After '47, February, then there was no monetary support, so when I came back to study I tried to see if I could get part-time work. And I did. Since my record was very good they just gave me a teaching position.

MERTZ:

The other alternative would then have been to go to work in industry?

WANG:

That's right. The other alternative would have, yes, but I preferred to study at that time.

MERTZ:

I see. Well, was there a particular area that you were interested in?

WANG:

At that time I was still studying communications engineering, you know, or actually applied physics.

MERTZ:

I was going to say this tends to overlap.

WANG:

They are almost the same, yes.

MERTZ:

And had you picked out a particular area that you wanted to do your doctoral study in?

WANG:

I picked out this nonlinear systems, yes.

MERTZ:

Was this something that you had discussed with Professor Chaffee?

WANG:

Yes, that's right, we picked this as the topic to write my thesis on.

MERTZ:

I see. And you didn't spend too much time on it actually.

WANG:

No, I only spent - actually I spent a half year and then a summer and then the next full year. That's all. And I got my PhD.

MERTZ:

You had completed most of your course work before then?

WANG:

Well, my masters was the same so most of the courses from the masters program I got and then completed a few more courses. So actually I completed most of the courses in the first six months.

MERTZ:

I see.

WANG:

And then I started my thesis in the beginning of September of — really, I think it started, the PhD topic, right about April — April or May and then worked through the summer, and then was starting to write my thesis in October or so.

MERTZ:

I see. Of the following academic year.

WANG:

Of the - of '47, yea.

MERTZ:

I see. Oh — of '47?

WANG:

Yea, I got back in February and I think I got my — April or May started training to have my preliminary examination in order to pass that before you go on to work on your thesis. I got it right through, so I had the problem picked out.

MERTZ:

About how much formal mathematics did you have?

WANG:

Oh, mathematics - other than - oh yes, at these other colleges and over in the masters program I had applied mathematics and quantum mechanics.

MERTZ:

Quantum mechanics?

WANG:

Oh yea. All these things.

MERTZ:

Did you have — but the mathematics was basically of physics origin?

WANG:

Yea, physics and applied mathematics.

MERTZ:

Were you exposed at all to anything in mathematical statistics of probability theory?

WANG:

Oh yes, we had mathematical statistics too.

MERTZ:

I see. And in the field of Physics —

WANG:

In the field of physics, I had normal college physics, later mostly in the wave theories and network theories, and feedback systems …

MERTZ:

I was wondering, from whom did you take quantum mechanics?

WANG:

Oh, quantum mechanics from Professor Schwinger. He was just promoted as full professor, the youngest one, only 29 years old.

MERTZ:

And he offered the course?

WANG:

Yea, at that time.

MERTZ:

Did you, in any of your course work or work up to your PhD, get involved in any lengthy computation problems of any sort?

WANG:

No, no computation. Never even had anything to do with the computer at that time.

MERTZ:

I see. So you never had much occasion to use any kind of computing machine, hand - Marchant or Friden?

WANG:

Oh. Those were used before, but that had nothing to do with the computers, really.

MERTZ:

But insofar as the kinds of problems that you had in the course —

WANG:

This was mostly theoretical, not much experimentation.

MERTZ:

Now that brings us more or less up to the time when you entered the teaching assistantship.

WANG:

Right. That was only part-time in the first semester. Then after summer Professor Chaffee offered me another scholarship or something so that I could get money without doing anything, so for the next full year I worked full-time for my thesis.

MERTZ:

Oh, I see. What did you teach when you were teaching?

WANG:

Mostly laboratory instruction and taught masters students conducting their laboratory work.

MERTZ:

In electrical engineering?

WANG:

Yes, in the same department.

MERTZ:

Then you worked full-time on your PhD?

WANG:

Then full-time for my PhD in September and February semester.

MERTZ:

Had you still not been exposed too much to any of the computers?

WANG:

No, I never touched a computer until I graduated and started to work for the Computation Lab in June or something.

MERTZ:

Let's come up to June.

WANG:

The middle of May, I think, because by the time, after I finished my thesis and final examination in May sometime there was nothing much for me to do, so then I started work there.

MERTZ:

The other question, had you ever had any courses in numerical analysis.

WANG:

No, I never had any numerical analysis. In fact, even after in the Computation Lab, my work was more or less in developing hardware part of it, rather than on numerical analysis.

MERTZ:

Then you were interviewed in the spring of '48?

WANG:

Oh yes, about April of '48.

MERTZ:

I see. And who was your - how did you hear about their work?

WANG:

The Computation Lab was just a part of, I think, and it was really just next door where I was studying, and somehow they told me they desired some people —

MERTZ:

They had a need for some people. So you —

WANG:

and I applied. At that time, I think Harvard got a contract from the Air Force in developing Mark III.

MERTZ:

Yes. And they were expanding.

WANG:

Yes.

MERTZ:

You talked to them, and did they have any particular area of activity?

WANG:

After I joined, then Professor Aiken indicated, "Well, this was in the early stage of computer development, there's a magnetic device, can you think of some way we could store some information in a magnetic material?" Nobody knew how to, at that time, other than tape. Because tape requires — at that time nobody knew how to get — In fact it comes back to me now, is that people knew how to record magnetic moving material like magnetic wire. Tape really had not been really popular yet. You can magnetize it and then when you move the magnetic material you will induce a voltage. So it required mechanical motion

MERTZ:

Right.

WANG:

and that's all. But mechanical motion is not very good, so somehow nobody knew how to record and play back without mechanical motion.

MERTZ:

And was this the way the problem was more or less put to you?

WANG:

Professor Aiken said, "How can we put information into magnetic media and get it back, without mechanical motion?"

MERTZ:

I see. And this was your first —

WANG:

He didn't mention mechanical motion, but how can we do better than using moving things.

MERTZ:

This was the first —

WANG:

This was the assignment when I got in about May or so.

MERTZ:

Of 1948?

WANG:

1948, yea. Then I think within a month as we were looking for magnetic material we found out some kind of — had a big chunk of this toroid about this size, which weighs about one or 2 pounds which had exhibited this kind of characteristic.

MERTZ:

The rectangular square root.

WANG:

The rectangular square root. Then I think, I suddenly thought that maybe if we passed a current in one direction and it was sitting — that's normally known. You pass a current on toroid and you can magnetize one way, but nobody knew what direction it fluctuates because nobody knew how to extract that information. Then I suddenly thought that by passing a current in the opposite direction, I could change the flux polarity from top to bottom, and in the meanwhile induce a voltage on the secondary so you will know it was in the positive direction and now changing back to negative.

MERTZ:

Now this is in reverse direction, not in orthogonal direction, rather 180°?

WANG:

No, it's not. Just one flux moves in that way, then reverses. At that time of reverse it induces a voltage because of the flux change if you put a winding there. That was the development really.

MERTZ:

A single winding. How could you measure — ?

WANG:

You just put a winding there.

MERTZ:

I see.

WANG:

You put a winding to drive a current feed in. One way to magnetize one way and the reverse current magnetizes the other way. Now if you always read it by sending one way, then after one read is reverse. The next time you read again there is no much flux change. And just that effect nobody knew at the time.

MERTZ:

Now how about the time? Were you interested in flux time so far as this characteristic was concerned, remnants of —

WANG:

Remnants are so large. They have some remnants you can differentiate between the two. Since its intelligence, since you only store one bit, you either store in the top or the bottom. You know it now. That means that electrically you can store a bit into the core and if you don't disturb it, it will stay there forever, then by sending a pulse you will know what information you stored and you can restore it later by sending another current back. And in the meantime, you can detect that there was one store or zero store there.

MERTZ:

I see. And you did this with a fairly large toroid?

WANG:

Just about this size, about three inchs diameter. It's just a toroid with a lot of material there.

MERTZ:

Then where did you go from there? You showed this to —

WANG:

Oh yea.

MERTZ:

Professor Aiken?

WANG:

Then I wrote a report, because every eight months we would have a report and from there how to use different material. We talked to the ferrite people too. And then, from then on - I mean that's the basic idea, that one bit of information can be stored in one magnetic material. Doesn't even have to be a toroid so long as it can exhibit this kind of characteristic, and it has a means to read it out. This was in June, I think.

MERTZ:

This was in June of 1948. Were you working with anyone on this?

WANG:

No, I was working on my own. Since I was an independent research fellow there.

MERTZ:

I understand that, more or less, the staff at this time is interested in — some of the personnel were Professor Aiken and Dan Moore.

WANG:

Dan Moore and Professor Aiken were there, but they were working on something else. This is the problem, how to store and bring it back, information in a magnetic material.

MERTZ:

Where did you go from there? From this point?

WANG:

From this point we went from, once you read out, how to organize into — once you know electrically without mechanical motion you can store information and you can read it out.

MERTZ:

And restore it without destructive read-out.

WANG:

No, it's destructive read-out. But since you know the information, you can always provide a mechanism to put it back. That's what present day core memory is. You read it out. It's destructive read-out, but since you know the status you can always put it back. So that means you have a way of a memory.

MERTZ:

Then what were you concerned with? Many of these?

WANG:

Then how to organize it. First, how to speed it up. That core - that big size core takes a few milliseconds time to drive it and come out with a pulse of about one or two milliseconds, you know. So the maximum frequency is about two millicycles per second. That's too slow.

MERTZ:

Is that still around.

WANG:

I think I can dig it out.

MERTZ:

The actual hardware?

WANG:

Yes. Later on we tried how to organize, not just one bit, but we wanted many bits. Then we developed a way to, from the output of one to feed it input for the next one. That's a sort of magnetic shift

MERTZ:

That's serial.

WANG:

serialized, yes. From then on we could increase the speed by using smaller and smaller material and the core getting smaller and smaller so that it can be faster and using the ferrite material you make it even faster without those current losses.

MERTZ:

Primarily your original work was —

WANG:

This was an improvement but the original idea of a way to store it and a way of read-out was done. That's the basic so-called invention, if you call it that.

MERTZ:

That was with metallic?

WANG:

That was with metallic. Its only importance is its magnetic hysteresis curve, so any material can be done like that.

MERTZ:

When you were considering an array of a number of these, was the uniform characteristic of these —

WANG:

You don't need uniform characteristic. If you are only using one current to send it in and one current to read it out.

MERTZ:

Even in series?

WANG:

Even in series so long as the input-output can match. At that time this was distributed and a few months later I think MIT sent somebody in. They had developed - not developed -

they had the idea for coincident type, matrices. They originally, I think, tried to work it on a neon tube and it never worked.

MERTZ:

They had an electrostatic gun. Oh, you mean in core?

WANG:

Not in core. They don't even know that core existed. At that time the memory was cathode ray tube, but I think Forrester or somebody at MIT had the idea of a matrix. That is, by somehow two high, two low, so they can select one out of a lot, using neon. They don't know that magnetic material exists. Then they heard of our development, they sent somebody over to talk about how do I read in and out of magnetic cores electronically.

MERTZ:

Was this Papian?

WANG:

Papian and Forrester. Papian visited me. We have the date, if you look at the register. It's about six months or four months after my report on the core.

MERTZ:

Which register is this? To the Lab?

WANG:

Oh yeah. The Harvard Computation Lab, yes.

MERTZ:

So that would have been in the fall of '48?

WANG:

Either fall or in early 1949.

MERTZ:

I see. One question that comes to mind now in connection with the next stage, you mentioned you reduced the size, thus increasing the time.

WANG:

We reduced the size in order to speed it up and then to organize to make it so that a bit can be transferred from one core to the next core —

MERTZ:

To the input of the next one.

WANG:

So that information can be shifted from one to the other. At that time we had a vacuum tube shift register and we called it a magnetic shift register. Then if we can shift from one to the next and this to the next, then it's possible to shift from that one back to this one here. So that by two cycles you can shift it here and shift it back. In this case I can preserve it without even - that is, read in and out without loss of information.

MERTZ:

Without destruction, yes.

WANG:

Right.

MERTZ:

You mentioned later the idea of a matrix array.

WANG:

But we never, at Harvard we never worked on a matrix array before.

MERTZ:

Were you or any of the people at Harvard interested in any geometrical configuration?

WANG:

I don't remember that at Harvard we ever — I'm the only one working on this core memory, and I'm not aware during the two or three years' time, that we ever attempted to do it on a matrix form.

MERTZ:

Did you attempt it in any other kind of geometry?

WANG:

We attempted it in the shift register type. In fact, the Mark III, the first Mark III was under construction already and the Mark IV used the magnetic static memory to shift from one to the other at about 20–30 KCs and used as the high speed memory.

MERTZ:

I see. So that was something that would be synchronous with the machine itself. In that later development, after you had demonstrated this essential characteristic, the remnants property and reversal —

WANG:

We were to determine a way of read-in and read-out and output to know what happens.

MERTZ:

Were there any others who then worked with you or were associated with you on this?

WANG:

Not too many because they were working on other things. For example, I had Peter Lingley, he was working on another area of the computer. There were other control parts, a number of other things, and one man was all we needed at that time to study.

MERTZ:

In connection with other …

WANG:

Eugene - Gene — who was he? He was instrumental in getting the material for me. So I could get a lot of materials for you, if I can go back and dig out the records. He got the materials from Westinghouse.

MERTZ:

I see. It would be interesting if you have some documentation relating to the materials —

WANG:

I would be very glad to send you some.

MERTZ:

and where you got the materials, what kinds you considered. You mentioned not only metallite, but the possibility of toroid.

WANG:

Oh yes. We had been talking to quite a few toroid companies.

MERTZ:

This would be interesting to know about. Also the problem of the production of these things.

WANG:

That I don't know, because at that time nobody was producing that yet. When I left Harvard Computation Laboratory at the end of '51, I think, this must just be starting to have some crude matrix for the memory.

MERTZ:

The way in which these things are arrayed, the history of the geometry is historically interesting.

WANG:

It did not start with the core. It started, that idea of the geometry, with the neon tube or diodes or other things. Only after the knowledge that by sending current you can read-out certain things and then with hysteresis when the current is small it won't affect it. Only when current reached certain size, go over the need, that your flux changed. Then the idea of coincident current, one current so it won't do it, but two times the current will.

MERTZ:

That then requires, when it's done in that way, uniformity in the material —

WANG:

Then that required greater uniformity in the material, right.

MERTZ:

to get the same remnants curve for all the material, which poses a production problem, quality control of the cores themselves.

WANG:

Also during that part of study we found that we can even store the different value of flux in the core. By magnetizing a little bit it would stop there and then more so that you — it's, I think, I also wrote a short note to the English magazine, I think in 1950, in their philosophical magazine, I don't remember.

MERTZ:

I see. I meant to ask you, do you have a list of your publications?

WANG:

Yes, I think I have some.

MERTZ:

That would be of help. This was the main area of your activity initially.

WANG:

Initially for the first year at least.

MERTZ:

That was fundamentally, I gather, in connection with the construction - the prototype activity for the Mark III and IV.

WANG:

Mark III and Mark IV.

MERTZ:

Could you describe what other activities?

WANG:

I helped, for example, to design the control circuit for the drum. Mark III had a magnetic drum memory. And in order to have an exactly constant speed, we designed some sort of speed control device. I also developed a diode matrix for conversions and logic unit diodes — two level diodes for logic input and output to convert from one pole to another or to do arithmetic operations for diode matrix.

MERTZ:

I see. Now this was — were you doing this also at the same time?

WANG:

Yes, that's right.

MERTZ:

Was one of these circuits for drum axis?

WANG:

Not axis. They already have a drum, pick-up, everything. Mostly to record some pulse there and feed it back, to make it constant speed.

MERTZ:

Oh, it's actually for the speed of the drum itself.

WANG:

The speed of the drum itself.

MERTZ:

To make it uniform.

WANG:

To make it uniform. The speed is relatively high.

MERTZ:

What would you say — you touched on one of the key problems of early electronic computers, the memory problem. The core memory development is crucial for —

MERTZ:

I think the core memory is very crucial for the computer industry. As proven in the last 20 years, the still major part is the memory. Even now, only gradually now the IC memory is starting to be used. It has been the main stay of the computer. All the others have been a lot of changes, improvements, and the core is the only thing, the basic idea of read-in, read-out still there. The only thing is they reduced the size using films. The magnetic film memory again is a core memory, because they are still using the same

square load material characteristics. So I consider it — it's just another medium. Yea, that's right. Film is still magnetic memory.

MERTZ:

If I might - some of the other kinds of problems. Any vacuum machine in that era, the late 1940s, early 1950s was sometimes faced with the problem of component reliability as far as the tubes themselves were concerned.

WANG:

That's right. The core had very good reliability. Since we needed a current to drive it, they used vacuum tubes to drive it. The first one we used, one of those transmitter tubes to drive 300 MA through. The tube, the vacuum tube was the major problem. I think in 1948, the same year, 1948, Bell Lab announced a semiconductor, but that's only for very little power, it's not applicable to the computer at that time.

MERTZ:

There was no serious consideration of it for some years. But certainly vacuum tube technology at the end of the war left much to be desired so far as tube reliability was concerned, as they found in ENIAC and some of the other machines. Was this a particular problem in the design or manufacture of the Mark III or Mark IV?

WANG:

I think that's one of the major problems. I think at that time the vacuum tube manufacturer and the government had a special — Western Electric, I think had some reliable tubes were announced, and I think all the computers at that time used a few of the standard vacuum tubes which were proven to be reliable.

MERTZ:

I see. Now —

WANG:

A lot more effort was put into making a vacuum tube more reliable at that time than actually put into core memory development.

MERTZ:

Yes. Even though the core memory was perhaps more serious?

WANG:

At that time the high speed ENIAC was still using vacuum tube. In fact, ENIAC used counting technique for the memory. It took ten counts to store one digit instead of using four bits to store one decimal digit.

MERTZ:

Yes. This activity you continued now through 1948 —

WANG:

1948, 1949, and then in 1950–51, at that area, I went. The basic thing is done, is already done so mostly it's a lot of people taking it up. MIT coincident core memory was picked up by MIT, RCA also working on that. Both Papian and Rajchman come to visit me after I announced those things in the Air Force reports.

MERTZ:

And that was in June of '48 was the report?

WANG:

Probably August or September.

MERTZ:

I see. Then both Rajchman of RCA and Forrester with Papian came to see you. It would be useful to know the dates of their visits. Where would I locate that?

WANG:

You can locate that. I might have some data, but I don't know whether I have it or not. There were a lot of people coming in. I think I had a lot of people visiting from England, at that time.

MERTZ:

So this development was one that did attract quite a bit of attention from people who were interested in precisely the memory problem. How about people from Princeton, did you have any?

WANG:

Princeton, no. I think it was that time the early version, from Moore School of Pennsylvania, I think that was a big group, and even at that time MIT with the Whirlwind (a related project) was still using the cathode ray tube for memory.

MERTZ:

I was thinking of groups that came to visit that were active in the field. You mentioned Forrester.

WANG:

At Princeton, what was that group there?

MERTZ:

Von Neumann.

WANG:

That's right. That group there.

MERTZ:

They used Williams storage in their computer; however, they were working at this time in building a machine.

WANG:

Yes. That was later taken over by the Bureau of Standards.

MERTZ:

I believe their machine was one that was run for ballistics tables, computations.

WANG:

The same as the Mark I and Mark II of Aberdeen Proving Ground.

MERTZ:

Or perhaps the Navy at Dahlgren, Naval Proving Ground. I believe they ran ballistics tables. Now, in this regard, would you say that the — Professor Aiken had pretty well defined where they wanted to go with the Mark III and the Mark IV?

WANG:

Oh, yeah. Mark III and Mark IV the system is already in operation. The basic components vary, depending on the state-of-the-art at that time.

MERTZ:

You might want to describe some of the other activities. Now you've touched on several areas that you worked on in addition to the core. That incidentally, I gather, was written up in *Newsweek Magazine* in 1949.

WANG:

That's right. At that time still nobody used core in the computer yet.

MERTZ:

That's right, yes. But at least the principle was established. Were there any other areas that you were active in the Mark IV or the Mark III?

WANG:

I don't remember. I think I tried to reconstruct. I have the whole Air Force report at home and I can look it over. If I think of something.

MERTZ:

This takes us up to about 1951.

WANG:

Then I left. I think, at that time Harvard decided that so many people in it, they were not going to emphasize the hardware development. IBM, Sperry Rand, UNIVAC. So I felt at that time I better leave, so I started my own company.

MERTZ:

Also in this year you were married.

WANG:

Yes, I married in 1949.

[End Of Side I Side II]

WANG:

I got the idea to start my own company, so I started it myself alone. I had a few hundred dollars saved. Also I got $1500 of the pension program from Harvard accumulated. They

said it was too small to accumulate for your retirement, so you might as well take the money with you now.

MERTZ:

I see. And that was your initial capital for going into business. What did you plan to do?

WANG:

At that time, I think, the magnetic shift register was just established. So I thought, since I know how to make them, a few cores and a few windings and a few rectifiers, so I thought I could sell them just as a starter, and then go into the digital equipment field.

MERTZ:

Did you have a patent on this equipment?

WANG:

Yes, I filed a patent. This is a copy of the patent. At that time we didn't even call it a memory, we called it a pulse transfer controlling device. It is really a memory. You read the inside and it's just the way the data can be stored there and a means to read it out and know what has been stored.

MERTZ:

It's very interesting, the patent history of this era. The patent firm handling MIT patents initially did not consider the pulsating current core memory worth patenting,

WANG:

I see.

MERTZ:

and recommended against it, because they felt there was no market for this, no commercial market.

WANG:

Do you know when this was?

MERTZ:

They recommended against this? It was - I'm not exactly sure - either late 1949 or early 1950, around in there. What was interesting about it was they said there was no commercial market for a core memory.

WANG:

Well, I think the same thing — I think when I wanted to file the patent, they said it's your patent, you go ahead and file yourself. They recommended a patent attorney for me. That's my present patent attorney, was recommended by Harvard, they worked for Harvard.

MERTZ:

You had more faith in the commercial value of the patent in fact than Harvard did. Did you have a market for it?

WANG:

In 1951, I think, had some commercial outlet because people all over the country bought a few pieces.

MERTZ:

So there was at that time in your judgment a reasonably good market.

WANG:

Oh, yes, a reasonably good market. But I never was in the coincident current part of it. Mostly I used the shift register type.

MERTZ:

From there then what?

WANG:

You see, the idea of memory is one thing. Then we concentrated only on the shift register, while MIT concentrated more on the coincident current matrix memory. But the fact is that a coincident current technique of reading a memory, the core memory itself is a separate development from coincident current.

MERTZ:

Now in that regard, did you branch out to make other components?

WANG:

Them, then after that we started to develop digital equipment and went into more systems. Instead of a small device, you tie them together to do more things and gradually larger and then into tape control systems and numerical control systems. And then we later came to the calculators and computers.

MERTZ:

Yes. Now, I take it, from a very modest start of your Harvard retirement and the patent on the —

WANG:

The patent was not granted until 1954, '55 I think.

MERTZ:

You still could produce under the filling, pending patent. What were subsequent patents?

WANG:

Oh yes, I filed quite a few subsequent patents.

MERTZ:

Do you have a list?

WANG:

Yes, I have a list I can give you.

MERTZ:

Of the patents you hold, and the work that you've done in the field of hardware development, of computing, what would you say is the most important?

WANG:

I developed just recently a special way of generating a log, an exponential solar ray to a simple circuit using our calculators. That also seems to me a fairly useful patent.

MERTZ:

I was wondering if you could describe the things that you felt were the most significant, that you had contributed in the field. Similar to the pulse transfer device. [Recorder off]

WANG:

One of the basic magnetic core memory patents, #2708722, I subsequently sold to IBM, I think, in 1956 or sometime. I think they used it quite effectively. Here is the list of all the patents.

MERTZ:

Of these, which ones do you feel are the most significant?

WANG:

I don't know. There is a triggering circuit, synchronizer. At that time I considered it important, but looking back it may not be as important. There is one on calculator organization, a log converter, which is very interesting, #3402285.

MERTZ:

That's a fairly recent one.

WANG:

That's a fairly recent one, filed in 1964. I guess I wouldn't want to mention too many more.

MERTZ:

Do you happen to know whatever came of some of the set-ups? You mentioned that the very first magnet you used is still around somewhere.

WANG:

I'll have to dig it out and see if I can find them. I think some are still around, yes.

MERTZ:

I was thinking also when you started to put these together serially and reduce the size, if there are any of those?

WANG:

Yes, I think I still have some of those mock-ups and some sort of simple prototypes.

MERTZ:

That would be very useful. People with whom you were associated in those days at the Computation Laboratory, whom do you feel would be interesting subjects to be interviewed, or might have some useful and interesting insights? You've already mentioned —

WANG:

I think you can talk to Eugene Grant.

MERTZ:

Eugene?

WANG:

Eugene Grant, G-r-a-n-t. He was with Maxson and he was with National - not National Cash — National? But I don't know where he is now, probably you can find out. He was with the Air Force working at that time.

MERTZ:

Is he around the Boston area?

WANG:

I don't know. I don't think he's around the Boston area. He was in New York. I haven't seen him for at least 15 years.

MERTZ:

Are there any others that come to mind?

WANG:

Peter Lindley. He was with Burroughs for a while and I don't know where he is now. I think of these two in the early stages as co-workers at that time in the same program.

MERTZ:

If there were a difference of opinion on the work in connection with the core memory, let's say after the original idea of being able to read out —

WANG:

After that, it was more or less an improvement on that. Mostly I was the only one working on that. Not too many people working on that. Others were more or less supervisory, report what you have done, you know.

MERTZ:

Ah yes. I see. Now, for example, Dr. Woo was also active in this work. Was his role more, would you —

WANG:

He didn't touch the core. He was in a supervisory capacity. He was working on something else, other circuitry.

MERTZ:

I see.

WANG:

Eugene Grant and Peter Lindley, they came in to look at what you have done, that's all. Actually the idea to read-in and read-out didn't involve any experimental work once you thought about it, it's there.

MERTZ:

You mentioned that there was some interest in England on this.

WANG:

That's right. There were a lot of people coming in and out all the time.

MERTZ:

Of course they did have some work, in Manchester particularly, there were groups, Wilkes working on William's tube and so forth.

WANG:

The Williams tube is mostly their development.

MERTZ:

Were there any other groups from any other countries that were interested that you can recall at this time?

WANG:

I don't recall that there was a lot of interest. Of course, there was interest generally in computers in general. I can give you these reports, monthly or quarterly reports that the Air Force required. You probably have that, do you?

MERTZ:

Unfortunately the records of the government are not always so easy to get. They are not the best pluckers of files. Patent Office materials are [inaudible]. Some of these materials we can copy and return to you, actually.

WANG:

I have four copies of the reports while working at the Computation Lab because that's an Air Force project.

MERTZ:

Ah yes, I would be particularly interested in the report and also some of the work you did in connection with the motion of the memory drum. … When you were exploring this characteristic there were some other memory devices available. What was - do you happen to recall what Professor Aiken's attitude was towards any of these? For example, in the field of synchronous internal memories there was the possibility of electrostatic storage tube, asynchronous external memories such as the mercury delay line. There was a thing being developed at RCA known as the selectron, which was a vertical matrix array within the vacuum tube for storage. There were a number of things. MIT had its own gun storage tube.

WANG:

That was still on a static storage base on the persistence of the scope phase and the means how to renew it. They had to keep on spraying with electron beams in order to continue it.

MERTZ:

That's right. They had two guns, one that would keep a constant …

WANG:

This was the most popular form of memory until the core came along to sort of obsolete that.

MERTZ:

Now in connection with your work, was it viewed as a, primarily as a need for the shift register, or as an idea in Professor Aiken's mind?

WANG:

I think that we continued going on to the shift register because that was, I think, mostly the design of the machine at that time required this form of a memory.

MERTZ:

So he viewed —

WANG:

Because before, the other Mark II and Mark III were using vacuum tube shift register as the principle form of memory. He viewed we could have a magnetic shift register that could replace it.

MERTZ:

So he didn't necessarily envision the broader application?

WANG:

He didn't envision the matrix memory form. That, I think, the matrix form of memory, is probably, the MIT program had a lot more activity. In fact, I don't think we pursued it at Harvard at all.

MERTZ:

Do you happen to recall if there were any people at Bell Labs at this time who were interested?

WANG:

Oh yes, a lot of people from Bell Labs came up too.

MERTZ:

Are those guest registers still in existence around the Lab?

WANG:

At the Harvard Computation Lab?

MERTZ:

This I haven't checked, I just wondered.

WANG:

I think it's possible they have them.

MERTZ:

That would be interesting. That is one indication of the general extent of the particular …

WANG:

Some of those coming in were going to visit the general lab. Mr. Papian coming in, specifically visited with me learning about the magnetic core memory.

MERTZ:

He started in 1949 working on metallic ribbons.

WANG:

That's right, in 1949 he started, yes, after he talked to me.

MERTZ:

I haven't yet talked to him, the last I heard he was in St. Louis, but his first work was to use metal ribbons. And that was, I believe, in '49 and '50. Then he later tried ferrite with not fairly good success initially, because of the lack of uniformity. That apparently was a serious problem.

WANG:

The ferrite core has a mold and the production, I think, I don't know, Phillips or somebody else, made it so it was uniform and practical in order to produce that.

MERTZ:

Yes, well apparently two different groups worked on the extrusion techniques of this, one using spaghetti manufacturing technique and another group using a different one in Chicago. Was your original, when you went into business for yourself, was your original facility located in Cambridge?

WANG:

No, I first located in Boston. I just had a second floor space about 250 square feet of space, smaller than this, room, and stayed there for 2–3 years. Then I went over, moved over to Natick with 6,000 square feet; from 250 square feet in Boston I moved to Cambridge with about 2,000 square feet for 3 or 4 years, and then moved to Natick with 6,000 square feet, for 4–5 years. Over in Natick, East Natick Industrial Park.

MERTZ:

Along with that went an increase in personnel?

WANG:

An increase in personnel. Then we moved over here to about 15,000 square feet and employed about 45 people. In the last six years, 1964, we increased to about 1400. Actually percentage-wise, I think, it's almost constantly increasing about 40–50 percent per year.

MERTZ:

Oh yes?

WANG:

Over the 19 years. Property-wise, it's more impressive in the last few years.

MERTZ:

What would you say were the most significant points in the development of your business?

WANG:

I think that since we moved over here, once we developed this calculator and started changing. Originally, it was one man or a small group, mostly getting government contracts or other contracts to build equipment on a special design, one at a time. Since we are over here, design started to develop proprietary products, careful to sell to everybody, with a fixed design using minimum amount of engineering talent and production and then later also marketing. That is the major change.

MERTZ:

When would you date that?

WANG:

We designed the first calculator in 1965, and then we were able to go into production and marketing in 1966.

MERTZ:

Prior to that time your greater emphasis was on one of a kind special orders, one of a kind. Do you date any of your changes or expansions to any particular kind of activities at any time that either required expansion — ?

WANG:

All this required expansion. At any time you look at it your expansion rate is about the same so you really cannot say "sudden expansion." When I started with one man, even if you hire a part-time help, that's a 40 percent increase. [Laugh] It's just as important as now to say let's add on a couple hundred more people which is only adding on 15 percent, you know. So when you look at any particular point, an increase by 40–50 percent is just as important. It's fairly uniform if you look at a logarithmic scale.

MERTZ:

In the early years this was also the case. You were by yourself for a while, or did you have some help?

WANG:

No, I was by myself, at least for a couple of months.

MERTZ:

With the capital that you had, you figured you couldn't expand enormously?

WANG:

I figured it this way. I'd take one year as an example, and since my salary when I left Harvard Computation Lab was $5400, so if I could manage to get $5–10,000 sales even the first year, half of them is my salary and the other half is for other things and that's all I need. That wouldn't be worth going and getting another job.

MERTZ:

And indeed that worked out.

WANG:

That worked out. The first year, I think, I had total sales of $15,000. Since I had a proprietorship, so that made my own income about $6–7,000 for that year. So it's not worse.

MERTZ:

It's not worse, and it has the possibility —

WANG:

That's right.

MERTZ:

Well, at that time that was an interesting and highly - well even now, speaking of risk, now it's in the risk area.

WANG:

Even in the Boston area, there aren't too many people starting in 1951 in electronics. All of them came later.

MERTZ:

I think the much higher growth was in the late fifties, early sixties. Then there is a much higher attrition rate in the late sixties too.

WANG:

That's right. At least I learned. During '50–'70 we went through a lot of ups and down too. If you look at our expansion, 40–50 percent a year, we do vary from that. If the general economy is slow the increase is slow, the general trend is that way. Just like we have a similar recession, general slow-down now.

MERTZ:

It has particularly affected the software more perhaps than the hardware, these days at least.

WANG:

That's right. I was experienced in that sense.

MERTZ:

Where do you envision the industry in general or yourself and your own firm in particular — What direction do you think it will take in the future?

WANG:

I think there is a lot of opportunity in the future. It seems to be this technology will keep opening up, with the ICs, transistors, IC and medium scale getting lower and lower cost, a lot of things you never dreamed of or even tried to do can be done now at a reasonable cost.

MERTZ:

You think this will be the coming area that your own firm is interested in?

WANG:

That's right. Yes.

MERTZ:

The medium and smaller scale activities, which are now economically more feasible than they were earlier.

WANG:

That's right.

MERTZ:

Do you see any particular area of application that might be —

WANG:

Oh, computers. Our calculators are just small computers, really.

MERTZ:

In anticipation of possibly new markets in areas that - do you think there will be some in the future that have not, in your own judgment, been explored?

WANG:

That's right. There are a number of areas.

MERTZ:

Can you think of any in particular?

WANG:

There are a number of things like controls and certain things which required a lot of circuitry. Our intelligence right now is - we are not doing it other than in the large scale computer, and gradually going into office help and, I think, into consumer products. There is no reason why, with a small trick one cannot do a lot of things, can get into personal computers.

MERTZ:

Highly personalized sort of thing?

WANG:

Yes.

MERTZ:

Well, I'd like to thank you for your participation.

WANG:

You're welcome.

[End of Interview]