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Medical Science Video Archive MSVA 167

Sir Martin Wood OBE FRS DL in interview with Sir Rex Richards FRS
Oxford, 10 June 1997, Interview I

Part One

RR Sir Martin Wood.

MW Good morning.

RR I would like you to start off our discussion by casting your mind back, if you can, to the very early 1930s when you were a small child in Oxfordshire, and tell us something about your parents and your home.

MW Well it was a long time ago. I celebrated my seventieth birthday a couple of months ago. You came, as you know. I was blessed to be born into a very secure, very affectionate family. I was the last of my father's six children. He had actually retired and I was one of his children in his second family. He had retired before I was born and had bought a ramshackle farmhouse in South Oxfordshire. He was a New College man and he had wanted to come back and had decided to be fairly close to his *alma mater*. So I saw a great deal of him and my mother of course. It was a very close, very affectionate family and has been closely connected ever since. As a family, it was a classic of its kind in a way. Both my grandparents, my mother's father and my father's father were vicars in the Church of England, and all the rest of the family were medical, nurses, doctors or missionaries. I was the sort of black sheep of the family; they never quite knew where that came from. But I learnt a lot from my father, who was retired and bought this old farmhouse and spent a lot of time doing it up and working around it, making things for it and so on. I used to go round and carry his tools and learnt a lot from that. I suppose, looking back on it all, the nature of their work and their parents, the families they had been brought up in, it was a family very much in which service to the community was the done thing. My father was the organist in the church. I always remember choir practice as one of the regular things and I used to pump the organ for him and so on. And my mother was the evacuation officer at the beginning of the war. I always remember going in with her and trailing along at her coat tails and collecting the children sent down from London, and then going around the village and finding places where they could stay.

RR And your father?

MW I am not used to people going to work. My father never went to work. I was not brought up in that atmosphere.

RR But your father had educated you in the early stages?

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MW Yes, he had worked all his life in the Board of Education. At the end of his life he was in charge of the education of crippled children. He hadn't got very much money and he saw no reason why he shouldn't teach me himself because he had retired, he'd got time, he liked teaching. He wasn't actually a teacher himself but he taught me then.

RR How old were you when you went to school?

MW Probably about eight or nine really.

RR And where was that?

MW I went to the Headington Girls School. Most people don't realise that in the junior part they take boys. I had a marvellous time, great fun. That was for a couple of years and then I went on to New College Choir School, not as a chorister, just as an ordinary prep school boy.

RR This must have been during the war?

MW That was just before the war and I was actually going to go off and live with some Swiss relations - we have got a lot of Swiss relations - to learn some languages. Then in 1939, when the war came, I couldn't go. I was sent to a school, Gresham School, in Norfolk, to which we went to for about three weeks until so many German bombers were coming overhead that they closed the school down and reopened about a month later in a hotel down in Cornwall. I had a marvellous time. We had the hotel just by the sea in Newquay. I spent the whole war there at school.

RR How old were you, and when did you leave that school?

MW Just at the end of the war. I was eighteen in the month the war finished in Europe.

RR And was that your first job when you left school?

MW No, in fact as you probably remember, labour was very scarce during the war. I had a job close to our home, which is very near here in Great Milton, where I was born, at Romaines Court in Great Milton. There is a strange little factory between Great Milton and Great Haseley which was making agricultural equipment, and of course that was kept going and boosted during the war when we needed to grow everything.

RR Oh yes of course. So you went to work there whilst you were still at school?

MW I went to work there during the summer holidays. My sister had been working there, I think she had hurt her back in the land army and you weren't sent home when you hurt your back, you were sent to another job. She was working in this factory, and then when she went back to the land army, the foreman asked if she knew anybody who could take her job on, and she thought her little brother might come and do it. I was fifteen at the time of my first job. Actually, my first day at

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work had quite an impact on me. I've brought a model of the work I actually did in that day. It was making agricultural equipment, and my job was to drill five holes in those bits of wood, which were actually then bolted around the wheels, the spiked wheels, so that when a particular bit of equipment was taken along the road it didn't wreck the road. There was a pile on my left with a big drill press with a drill and I used to yank a handle down and drill a hole and I held a pile of these bits of wood. It was a production line and my first introduction to mass production. The man had cut out these bits of wood on my left and I passed them on to the man on my right when I had drilled the holes in. I put a little steel template on the top of it, held it there, drilled down, positioned it under the drill; it didn't take me very long. I had about twenty seconds training on the job, you see. Then off we went. I started drilling with these machines and you can imagine it didn't take me very long to feel that I could make life easier for myself by doing two at a time.

RR Putting them together.

MW Yes, putting two together under the template, just drill straight through and making sure it was straight. That was fine. Then I did three and then I did four. I found four a bit much for my little hands, so I went back to three and it was just as quick. I don't think it took any longer at all doing that.

RR So you were piling them up on the right.

MW Yes well, when I started there was a sort of stack on my left of undrilled ones and a stack on my right of drilled ones. By the end of the day there was a rather embarrassing bare floor on the left and a mountain on my right. I remember being called into the foreman's office at the end of the day and I thought well maybe he'll say what a clever lad I am, and give me a pat on the back, instead of which he merely told me that because my sister was eighteen and had been paid one and twopence an hour, and I was only fifteen, I was only going to be paid sevenpence. I remember going home absolutely furious at the end of the day and sort of kicking the stones, you know that bit of the road that goes past that famous restaurant Le Manoir Aux Quat Saisons. I was furious. Anyway in hindsight, I think it taught me a couple of lessons. First of all, there are very few jobs in the world that you can't actually make more efficient, you just sit back a second or two and think about them. I mean I tripled the productivity of that machine in twenty seconds or something. Secondly, the thing that lasted all one's life is that it pays to train people and look after your staff. Train them and praise them when necessary and encourage them.

RR Give them credit.

MW Yes give them credit and so on like that. I then went on actually after school as I became eighteen just at the end of the war, literally the month the war was finished and though I don't think I would have been a conscientious objector, the war had finished all round the world and people didn't know quite what to do with servicemen. As I wasn't very inclined to put on a uniform without any real purpose for it, the only alternative was to go down the mines, so I went down the coalmines. I became what was called a Bevin boy.

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RR So were you sent there or did you just sign up, and did you have any choice about where to go?

MW I had a choice. You had the choice of the very first place just as if you went into the services, you could say you were going into the air-force, or the navy, or the army. So if you went into the mines you could say I want to go and work in that mine. I had a little bit of knowledge. I had some friends in South Wales who did a little reconnaissance for me and I said the most important thing is to find a mine with good pithead baths, because you get much better digs if you can wash and come home clean. So I found a mine with some very good pithead baths in Deep Duffryn Colliery in the Aberdare Valley and went down there, and that slightly added to my feelings about industry. I found the environment very interesting having come from a sleepy Oxfordshire village and somewhat unreal world if you like, detached from industry and main activities of the cities. Suddenly going down into the Welsh valleys and going down and working there, it was a great experience. I enjoyed it in a sort of masochistic way, but the whole environment was confrontational. It was before nationalisation. There were the owners, there were the managers, there was us working in the mines, and there was conflict absolutely everywhere.

RR All very hierarchical.

MW Hierarchical and everybody was fighting each other. It was so inefficient, unbelievably inefficient. Looking back on it, I think it is true. I don't think I have made this up from having thought it through, but the concept of one day trying to start a little business of my own, a company of my own that would be not only more efficient in the sort of technical side of things, but would somehow harness the human spirit in a sort of way that was more enjoyable and productive, I think it dawned then. It took a long, long time to come through, but the inefficiencies and the basically pretty unpleasant...

RR That was quite a traumatic experience in a way to see all this.

MW Nothing was as traumatic as the first day in that little factory in Great Milton, but it was a slow thing over the years in that industry. Well, we know what has happened to the mining industry now, it has virtually disappeared. If they had operated in the way of collaboration and teamwork and commitment and so on, we might still be an important mining country.

RR So how long did you stay in Wales?

MW I was two years underground in Wales, and they actually changed the laws and from that time onwards you could ask to be moved somewhere else. I went up, after working in the Welsh mine where it was extremely primitive, one walked for about a mile underground and it was all with pit ponies and there was no mechanisation at all - you were just with a pick at the coal face - I went up just to see the difference, what modern mining was like, to a mine in Derbyshire where it was totally mechanised and the output per person was something like twenty times as much, I think.

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RR Gosh.

MW You probably worked a bit harder. I always think working with machines - people say it makes life easier. You have to get a lot more done, but you work a bit harder yourself too.

RR How much longer did you stay in the mines in Derbyshire?

MW About a year.

RR You then went on to Cambridge didn't you? How did that come about?

MW Yes well, the sort of ideas I had at the time. I saw so much wrong with the coal mining industry in that rather young arrogant way, I thought I would be interested, at least for a period, to go into mining as a career and I was given a Coal Board scholarship. I went to Cambridge and learnt engineering and then actually on to the Royal School of Mines, to learn a more directly relevant course. Then I went back into the mines and then six years older, a little bit mature, I realised after a couple of years that it wasn't quite the thing for me for life.

RR Then how did you get out of it?

MW It was difficult actually, because if you are underground six days a week and recovering on the seventh, it is not easy to, and with very little holiday and not very much time to think. I actually got, through my family who were still living in Oxford and were involved in the university circle, an interview with the Professor of Engineering. I took a day's holiday and came down to see him.

RR That was Professor [Alexander] Thom in those days.

MW Yes that was Professor Thom.

RR He became a great expert on Stonehenge didn't he, at a later stage?

MW Yes I think he was, and also the glazed castles in Scotland.

RR Yes. He was a rather interesting man.

MW Very nice. I think he was surprised to see this young coalminer walking in through the door and asking for a job, but anyway he said 'Fine'. He'd got a job as a young demonstrator in the department. I didn't know what a demonstrator was then, but he said there was some money tagged to it and it would keep my family. So I went back home and handed in my notice.

RR Now, had you married Audrey by then?

MW Yes. Audrey married a coalminer. We were married up in the north. Both her grandparents were ministers of the Methodist Church and also, just like in my

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family, the siblings were all medical, so were all hers, medical or in the church. We were very narrow.

RR So you and Audrey came down to Oxford to take up a job in the engineering lab.

MW Yes we came down to do that. And that was also a slightly traumatic morning because when I went in to see him he said that he was very sorry but he had just heard from the University Chest that there wasn't any money for the job. He was a very nice guy and said, 'Look I'll give you a bit of tutoring and you can do some drawing, teaching drawing.' I have always enjoyed teaching.

RR But engineering drawing.

MW Oh yes engineering drawing. So we started doing that but he said, 'I have got a college friend called Nicholas Kurti who works in the physics department across the road and I think he is looking for a young engineer. Why don't you go and talk to him?' So I went across the road and knocked on the door. A lot of what's happened to the rest of my life has flowed from that.

RR Now Nicholas had come from France I think, hadn't he, during the period between the wars?

MW Well Nicholas is a Hungarian and he actually left Hungary and went to Germany because when the Jewish people were being barred from professions in Hungary he went to Germany as a free and liberal country. Then after Hitler came to power, he was working with Simon. He went to Germany to work with Nernst in Berlin, and then to work with Simon, Sir Francis Simon came later, to work in Breslau in Poland and they got I believe, Simon once told me, the biggest cheque the German government had ever given to a physics project, to build a high magnetic field, low temperature department in Breslau, and this arrived in the week after the Reichstag fire. Simon was quite a shrewd character and he could see which way things were going and he made his plans to come over to England, and he and Kurt Mendelssohn and Nicholas Kurti...

RR So they already had the low temperature physics going?

MW Yes. I think they came in the mid thirties, late thirties and then it was all held up during the war of course, but they were just getting going again.

RR So what did Nicholas want you to do?

MW Well Nicholas and his colleagues had been building the equipment with which to do research at low temperatures and in high magnetic fields. They bought this big generator, 2 megawatt generator from Manchester, which used to run the trams in Manchester, and connected it up. But the actual engineering facilities required for generating high magnetic fields required a lot of time and effort and took both him and his colleagues and his research students off the mainstream of their work. And he just thought the time had come to have an engineer who would make it

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his job so that they could switch on magnetic fields rather like compressed air or water and so on.

RR I remember that wonderful old generator because I was always fascinated by it because it had a huge flywheel, and yet when it was running it was so beautifully made that there was hardly any noise, apart from the swish of the air through the flywheel.

MW Yes it was a fabulous machine.

RR It must have been made before the war I think.

MW Oh yes. I should think probably in the twenties.

RR It was a very fine piece of engineering and that produced 2 megawatts.

MW Well there was a motor.

RR An electric motor.

MW An electrical motor that drove it because the trams needed DC. It was a three phase motor that drove this thing, 2 megawatt machine. It had two, 1 megawatt generators which produced the DC.

RR You couldn't just switch this thing on though could you? I mean did you have to ask when it was convenient, particularly after the war?

MW Yes. Well at that time Oxford had its own power station, a 25 megawatt power station down in Osney Mead, it is still there. It is now part of the Engineering School. Oxford is obviously connected up to the grid, but we used that 25 megawatt station. So it meant that when we were running flat out we were using just under ten per cent of Oxford's power supply. And Simon was extremely good at negotiating this sort of thing, very good for getting money, getting equipment for his grant, marvellous, an ideal professor, a model professor on that sort of front; he had negotiated with the Electricity Board. I think we had only paid five per cent of the regular cost of our electricity if we did not work between the hours of seven in the morning and seven at night for the four winter months.

RR Oh yes.

MW That had quite an effect on me too, because he said I had got to live within five minutes bicycling distance of the lab so that he could call me in at any time of night in the winter when they were running at night, which they often did. However, we often used to run during the day because the electricity people, I got to know them there, and they said 'Well, look if it is a warm day in the winter and we are not flat out, just ring us up and we will tell you if you can start up.' So I used to ring the power station and I don't actually remember ever being refused. We still got ninety-five per cent discount on the cost price and used it basically all the time.

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RR That was terrific. So what was your job there, apart from just running this great piece of machinery?

MW As you know you generate a magnetic field by putting a current through a coil of wire, and if you do the sums you will find that you need a lot to get to a high magnetic field. Simon's great thing in life was always to push samples, anything he was working on, absolutely to the limit, high magnetic fields, high pressures, low temperatures or high temperatures. He got a lot of money out of De Beers for doing work on diamonds. Always pushing things to the limit. Occasionally he used to say, 'I should like to push my research students and staff to the limit,' which they willingly did. A tremendous character. You knew him I suppose?

RR Yes, I did but not very well. I was very young when he was still there.

MW I didn't know him well, but he was a great man, very firmly fixed in the memory of everybody who worked for him. If you do your sums you'll find that you do need, in fact, megawatts of power to produce fields that are of use, of serious use in physics experiments. In fact most modern laboratories now have, instead of 2 megawatts, an American one has just built a magnet that has 40 megawatts with an overload of twenty-five per cent. So to answer your question, there is a big engineering facility. Starting at the transformers from where the power comes in from the grid, through to your own building, the generators or rectifiers sometimes used now, and all the cables, bus-bars, switches, the control mechanisms on the smoothing, because you want a smooth current, up to the magnets themselves, then of course you have got to cool them. So we cooled the magnet in the Clarendon, we had a 100 ton tank of de-ionised water on the roof and a lot of pipes right through the building with pumps and switches, quite big pipes. What with the monitoring equipment and all that, it just took a lot of time. I think, very sensibly, they thought it was a good idea to have somebody who was...

RR Can you tell us something about the design of these coils?

MW There are two problems in the design of the coil. One is to make them small enough so that the current in the coils is close to where you want the magnetic field, so you want a very high density current and at the same time you have got to have enough space somehow in the coil so that you can push the water through it to keep it cool and stop it melting. I brought, as you can see, a whole set of samples of coils. This was a coil which Nicholas Kurti and his colleagues, actually a French design, a French Chinese gentleman, who worked in Saclay developed this. Initially it was very, very clever, very simple, which consists of a coil in which you have a copper strip, just over an inch wide and about sixteenth of an inch thick, around which nylon mono-filaments had been wound around the tape and then the whole of the tape with the mono-filaments wound into a coil, so that each turn is separated from the next one and yet water can go straight down through that. If I lifted this up you could actually look through it. Can you see through it? The water just goes straight down. It has got a very big cooling area and they were very reliable, these coils. You stack them up, you separate them with insulating spacers as it stacks up. Water went through the magnetic field down the centre. It is like a big, what do you have at the bottom of your coffee pot?

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RR Sieve?

MW No the actual heating element. I can't think of the word.

RR Oh yes.

MW And you just had to see. They didn't last all that long, a coil like that, because even if you used pure water it still conducted a bit, you got a bit of corrosion there, and they lasted a year or so. We used to take them out and clean them a bit from time to time. But the other problem is that they are not very rigid mechanically, there is a bit of squash, it feels fairly rigid, but eventually the Lorenz forces... The generator gave 4.5 thousand amps - 450 volts went across this and the Lorenz forces were quite substantial pushing this out, and there was a man...

RR The thing is tending to fly apart because of the effect of the magnetic field and the current flow.

MW Yes. These remained almost to the end the sort of backbone of the Clarendon magnet business, it is so reliable and in point of fact there are engineers around the world, and I might have been one of them, that try and make fame in getting the absolute highest possible magnetic field. Whereas in fact the output of the physics research was much better, usually better. Perhaps designed to the limit but draw back a few per cent so the thing wasn't as liable to blow up, but was always there when people were wanting it.

RR Now tell us about the other designs.

MW Well these other new things that came here were developed by Professor Francis Bitter in MIT (Massachusetts Institute of Technology), where they had something like five times as much power and of course the forces were that much greater. And instead of having the water coils like that, he developed a system whereby you stamped out a copper plate like that with holes in it and then you slit it at one point and you built that up into a spiral coil and you put a similar spiral of insulation. You had a similar coil you built up of insulating material which you slid into that and then you clamped that tight and..

RR Yes, you can see that that is mechanically stronger.

MW Much more strong mechanically and you had the other advantage that because the actual path of the current is much shorter towards the middle from the outside and you had a current density inversely proportional to the radius, you got a much higher magnetic field. The difficulty of this was that the only way it was cooled was on the inner edge of those little holes.

RR So the contact area was small.

MW Yes the contact area was small with the water and the copper and that has always been the problem in those coils. If they work and when they are really well

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designed, they are really like racing cars. They work very well but they need a tremendous amount of maintenance and repairs and so on.

RR And then you made an improvement on this.

MW Well it actually led me on to, I think, the only original idea that I had, which I find it easier to draw than to gesticulate.

RR Do.

MW Because if you look at that you can see if I can draw that *(Sir Martin draws at this point*). That is a little bit of that coil there where you have got rows of holes. I am not doing the exact reproduction.

RR That doesn't matter.

MW The water is...this is the copper and the current is zooming round...

RR Going round, yes.

MW And the water is going in that direction. It so happened at that time that Cyril Band who was in charge of the photographic department in the Clarendon was developing a chemical etching process, some other work altogether, totally different. I was often in touch with him and when I showed him one of these he said, 'That must be expensive to make a punch to punch those things out. Why don't you let me do it? If you give me a copper plate, I will not only etch around the outside and the inside and the slot but I will do all the holes too.'

RR Yes.

MW I thought if you are going to do that you wouldn't put up the electrical resistance much if you made those holes a bit oval and you could double the cooling area without increasing the electrical resistance. And I can remember on the way home that day I thought, because one of the other problems with this is that the plates were very thin, because our generators got this high impedance and it would be much more efficient to have thicker plates there and why should you not just join those up? And so you, in fact, have got a series of concentric, helical coils and complete outer surfaces, inner and outer surfaces of each one...

RR Much more efficient.

MW Far more cooling, and you have still got the current distribution. You can design the current density distribution as you like and that is the sort of coil that appears at the end of that.

RR Yes.

MW Which is ...

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RR I understand that that now is absolutely the standard technique which will make these very high field magnets.

MW Yes. Well, to be honest they are very difficult to make but they do actually, if you get everything right you spend the time and the money and so on, you can develop higher fields than any other way so that the very highest fields in the world are still made by this method. It has been developed very extensively in Canberra, in Grenoble and now in the high field lab in Tallahassee in America, where they are all doing it. They are called polyhelic coils and they all came from that idea, that very simple idea.

RR So this was about the time when the idea for the company came along wasn't it?

MW About that time, because other labs were getting going and they used to come along to the Clarendon and see what we were doing. A delightfully uncompetitive community as it then was. It was part of my job to tell people how they could reproduce the work that Simon and Nicholas were doing, which was becoming famous, and people wanted to get it onto the same lines of research. I showed and told them what they needed to know for generators and pumps and switchgears and so on. One thing they couldn't buy anywhere were the actual magnets because we designed these in the Clarendon and made them and there was no know how about it.

RR When did the great decision to start a company come about?

MW Well, it didn't start quite then because right at the very beginning I used to tell people if they came, if they really wanted something close to what we were doing, and they sent the Prof. a cheque, I would get my technicians to come in, in the evenings or weekends and make them then, one or two magnets for other laboratories like that. And then first, two things happened that made me think about the company. First of all, the work actually began to clog up the workshops a bit and the people in the lab literally didn't like seeing lathes left at the end of an evening so they couldn't be used the next day, with something in the chuck. Also the work began to increase, the number of people coming in and asking this that and the other. I just thought here is an opportunity for starting a company. Actually, a little bit of thinking had gone on before that because I told you that my family was rather medically orientated and my eldest brother, in particular, was a surgeon who was always complaining about what he saw as poor design of some of the equipment.

RR He was working in Africa by then?

MW Yes and he started the Flying Doctor Service in East Africa. I mean he saw it at its worst, because he used to go out to all the bush hospitals, you know, where all the scissors were rusty. But anyway he was always saying 'Come on, you're the engineer in the family, can't you design and make something better than this?' And on top of that it so happened that my father was, or my family, was related to Gathorne Girdlestone, who was quite a well-known orthopaedic surgeon in Oxford. In fact, my father and Gathorne Girdlestone designed the Wingfield Hospital, now the Nuffield Orthopaedic Hospital, because they both had ideas. My father had been

in charge of the education of crippled children and in those days children were in hospital for months, years at a time. I mean, now the techniques are quite different and so on, but often large chunks of their education happened when they were in hospital, and my father had ideas of how this could be done better than it was at the time and they decided they would like to build a model orthopaedic hospital. He designed this and went along and saw Mr Morris, as he then was. He was making lots of money making motor cars and got a big cheque off him and built the Wingfield Hospital, but that was another source of pressure. I used to go round the hospital with Gathorne Girdlestone and even in those days I could see how crude a lot of the splints, the equipment, the things were in those days. Actually, another influence on this is that Audrey's eldest son, my stepson, had polio when he was young and had problems with his legs. He was paralysed from the waist down. He has recovered a great deal since then but he has still got some muscles missing in his legs and he had splints, and in those days, believe it or not, you couldn't get splints with a hinge at the knees.

RR Really.

MW So he was either trying to walk around without splints at all, and often falling over because he just couldn't hold his legs straight, or he was in straight splints which were obviously very bad for him if he was in them for too long. When I was at the Royal School of Mines, it was a long time before, I made some splints with hinges on them. They looked rather like some of the museum pieces we have got down here, but anyway it is absolutely standard nowadays. I was always interested in those things and I had the idea of starting a medical company, giving into family pressure a little bit on this. When the possibility of starting something up making magnets came along, half my feeling about that, that was a way into business. I'd got enough of the salesman in me, so if someone gives you an order you say yes, and do something about it. I thought later we would move over to the medical side. There comes a story perhaps a little bit later, on that side of things. Anyway I went to Nicholas one day and said...

RR That is Nicholas Kurti?

MW Yes. 'What do you think, I've got an idea of starting a company? That was again a sort of magic moment in my life because university attitudes to industry were built up largely either in ignorance or if it wasn't ignorance, it was condescending. They thought of industry as the Morris Works on the other side of Magdalen Bridge, always full of problems and strikes and what have you. Nicholas however, I remember him coming forward and grasping the lapel of my coat and saying, 'What can I do to help you?' Absolutely straight off.

RR Marvellous.

MW I mean he had a terrific influence on Oxford Instruments, Nicholas. First of all coming from the continental European environment, where industry and academia work rather closely together. And secondly the whole Jewish ethos is rather down to earth and you see national boundaries not in quite the same way as other people do. So Oxford Instruments has always worked closely with academia and has been

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international. We have exported 80 to 90 per cent of everything we have made since right at the beginning. So it became absolutely natural to us.

RR Where did you start the company? You must have had some room for equipment.

MW We started it in - I used to live in 25 St. Margaret's Road in Oxford. We pushed the furniture in the sitting room up one end and started to work the other. That is the way small firms grow. We then moved into the garden shed in St. Margaret's Road, which was tiny, a very difficult place and you could hardly get there from the road. And fairly soon we decided to move. It was a very tall house, it wasn't a very convenient house. It was on five floors I think. It wasn't very good for my stepson too, because of all the stairs. He was always going up and down stairs. We'd looked around in North Oxford, within five minutes bicycling distance of the Clarendon, looked around for somewhere with a big garden, because both Audrey and I had been born in the country and wanted really somewhere with a bigger garden to bring up the family. Somewhere also where we could build a bigger shed at the bottom of the garden and for this not to be seen, because it is clearly illegal to do industry in an up-market residential area like North Oxford. We settled in a house in Northmoor Road, which you have probably been to, which by geographic accident had a plot for two houses. Some man had come along and said he would buy both plots and built a house there. It was marvellous.

RR Yes, because it had lots of space there.

MW So there we built our first purpose-built building, it was quite a substantial shed at the bottom of our garden. We started work there but, in fact, just as we were moving and doing that, came really one of the biggest bits of luck, call it what you like, in our history, when superconductors came along.

RR Ah yes. So that was 1961. So you had just moved into that and got the company going.

MW I can't remember the dates exactly, but it was pretty much at that time.

RR So you went off to this conference in MIT.

MW Yes, well a great bit of the history of our company was this conference in MIT in the autumn of '61, which when it was planned at the beginning of '61, was planned simply as a meeting ground for the people who made copper magnets and for the people who did research in them. It was very nice and small, there were only about ten labs in the world that were involved and the physicists in those labs and we used to meet. The physicists would say what they wanted and the engineers would say whether it was possible or not and how they could do it, and so on. It was a very nice meeting. However, I suppose it was planned by two people called Dr Henry Cole and Dr Bruce Montgomery; Francis Bitter was the head of the department at the time. Between the time they planned it and the time of the conference there were some remarkable developments in the discoveries of Type II superconductors. They had been coming slowly.

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RR Perhaps you should explain that Type II superconductors are superconductors that will sustain a high current even in strong magnetic fields.

MW Yes. They are conductors in which the resistance is zero anyway. So that if you can wind a superconducting magnet, you don't need any power at all to operate it, so you get rid of two of the very big problems of producing the power, developing the power and getting it into these sort of coils, and because you don't have to get rid of any of the energy there is no heating and lighting, you don't have any cooling system. You get lots of other problems, but two very big engineering problems have just gone.

RR Just disappeared.

MW And this meant that if any of the people with ... I mean it was far cheaper, the actual magnet itself was fairly expensive, because superconductors were expensive and the environment to keep them cold, you had to operate these things in liquid helium, which didn't come too cheaply, but it was still a tiny fraction of the cost of having a big engineering facility, with megawatts of power.

RR But the MIT conference, there was this additional session which you told me about.

MW Yes, as you know superconductivity was discovered in 1911 in Holland by a great man, Professor Kamerlingh-Onnes, but it took a very long time before it got out of the research lab. There was very little helium around. He had the only helium liquefier in the world and he discovered it, and work at low temperatures was very difficult. That was 1911. It was a sort of rather mystical subject that few people had worked on for years and years and years.

RR And the materials that he worked on wouldn't sustain a current in a strong magnetic field?

MW No. They reverted to the resistive state as soon as you either put them in a magnetic field or put a current through them, which is the same thing. And it was not until, I think just after the war, I think it was first done in the Soviet Union in the Ukraine, by accident, a man I think it was Schubnicov(?) in Krakow.

RR But the poor man disappeared didn't he?

MW He was a creative man, a revolutionary man in many ways and not only wrote lots of books and probably, to his credit, developed the so-called Type II superconductors, which would continue carrying a current in a strong magnetic field, but he was also politically active and disappeared one night and was executed.

RR Poor man. But let me take you back to the MIT meeting.

MW This is not known in the west. It was one of those extraordinary things that the curtain between what was going on in Russia and the west was such that people

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didn't know what was going on, and it was discovered, I think quite independently in the west within a few years after that. And there were signs during the fifties of the same materials that appeared and somewhere about '55, I think, some people found a material called niobium-tin. They grew crystals of niobium-tin in which you could pass a current in a very high magnetic field. It still took about five years before there were actual wires and conductors available, and it was during the time just before this conference that a few materials actually came on the market, or were available. There wasn't a market exactly; they were able to get small amounts of material. They were reported and they planned in this conference, at the end of the week, they said that there were going to be a few interesting things and an additional session, a Saturday afternoon and you know at the end of a busy week, most people are going home on Saturday...

RR Quite...

MW The place was the Kresge Auditorium, I don't know if you know it. It is just on the side of the Charles River. It was absolutely packed and people were sitting in all the gangways and so on and listening to the people from Westinghouse, from RCA, from the Lincoln Labs and so on, all reporting on this new material.

RR Very exciting.

MW And there were fields up to 40, 50 kilogauss, 4 or 5 tesla, reported then and I remember I went back.

RR Did you have Audrey with you then?

MW Yes.

RR She was travelling with you.

MW Yes, she was always interested in these things. She used to come in quite often in the previous days of the Clarendon, helping Nicholas and so on and writing things down. She was very much involved with it before we started the company. I think it was actually in the underground in New York, later that day, on the way...

RR You were on your way home?

MW Actually, we went around on a long trip around the States when we were over there, but I think we had flown down and we listened to one or two physicists in the plane flying down from Boston to New York who were all saying, 'I don't think superconductors will ever get used, these incredibly difficult materials and they use liquid helium and that is much too expensive and difficult.' I can remember listening to people - there were some physicists in front - and thinking, they don't know what's coming, so to speak, if there is a demand. Because we knew that people from Oxford industry wanted the magnets. If you could produce a magnetic field that we saw, at a fraction of the cost, liquid helium would become available.

RR Quite.

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MW And we decided in one of those moments in the underground in New York, when we got out we rang up the man who was making this in, I think it was called, the Wah Chang Corporation and ordered a pound of wire.

RR Gosh, and how much did that cost you?

MW Well it was the first genuine R and D [Research and Development] product of the company. It cost the whole of two hundred pounds, which was a lot of money, it was more expensive than gold, I believe, in those days.

RR Was it really.

MW And this is what we made of it. That is the pound of wire. In fact it wasn't niobium-tin because that was such difficult stuff to make and it took years to come along. This is niobium-zirconium wire, you can actually see it there because it has got a transparent insulation of nylon that is actually nylon mono-filaments, rather like that, wound round it and then it was fused so it was covered.

RR Yes, made a complete film.

MW It comes up to the contacts there.

RR So you wound that magnet at home.

MW Wound that in the shed at the bottom of the garden, the shed was just finished. Nicholas Kurti organised a glass cryostat and we hung it from these three hooks, it was from nylon from the top of this glass cryostat, poured the helium in and I brought the battery of my car upstairs, got an old rheostat, cranked the rheostat and we developed 4.1 tesla in that magnet, from my car battery which would otherwise, if we had used any of these coils, we would have required somewhere between 3 and 4 hundred kilowatts of power.

RR Amazing isn't it.

MW We just had a little cryostat.

RR Just hung it in.

MW Just hung it in and just cranked up the battery. That was absolutely the turning point. I mean that was pure luck. There are lots of different kinds of luck.

RR You have a nice photograph somewhere, which I have seen.

MW Yes I do.

RR Of you lifting this ... perhaps we could show it later on.

MW Okay yes.

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RR But the success of that magnet created quite a sensation didn't it?

MW It did, but really I mean Oxford Instruments core technology ever since - we do quite a number of other things, perhaps we might talk about later, particularly the medical things and so on - we have developed a position in development of magnetic fields, use of superconductors, and the cryostats and all the low temperature equipment that you need to operate them.

RR Yes to go with it.

MW And that has grown and grown and grown.

RR So when you realised that this magnet was such a success, I imagine that you appreciated that you couldn't continue in the garden shed for long.

MW Coming back to that, you said that I had built this garden shed and so on, actually it didn't last very long because you know we had a young man who had a noisy motorbike who used to come every morning and help us. Joe Milligan was the very first person, a retired technician from the Clarendon laboratories, he was wonderful, he had worked all his life in the Clarendon.

RR Very skilled.

MW Yes, very skilled and very versatile. But when we actually needed more strength and more effort we got a young man who used to come in on this motorbike and I had a feeling that if this went on, and we had two, three, six motorbikes coming every morning down Northmoor Road... We actually had the Chairman of the Planning Committee in Oxford living right opposite, Michael MacLagan, and we had Janet Young, Baroness Young, living two doors the other way, she was in education. I mean it was full of people on various committees. I did check with the City Council with somebody I knew and I said, 'What happens if we are caught out?' And he said 'Well it is totally illegal what you are doing, but if anybody does complain, you won't be shut down at once, you will be told and you have a month or two and you have got to stop.' It made me feel a little easier. In fact, we made no noise, I mean compared with the noise made by our neighbours with their motor mowers and so on, we were quiet. I planted lots of trees around it and you couldn't see the place.

RR Then where did you go?

MW We went up into a disused slaughterhouse that we found in Middle Way, No. 3 Middle Way.

RR Was that the place I knew as the cake factory?

MW Yes. Right across the road from the cake factory with the tennis courts and so on, yes. It was a slaughterhouse, which belonged to Mr John Lindsey the butcher; his father had used it before the war. During the war when slaughtering was somehow brought under much wider controls, he wasn't allowed to use it, and he had given it

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up and when we went into it, pole-axes were still hung on the walls and there were pools of dried blood on the floor, bicycles for delivery were upstairs and we just converted the whole place into a little factory which was marvellous.

RR And what was manufactured there?

MW Everything.

RR How long did you stay in Middle Way?

MW A long time actually. There is quite a story that hangs from that because we finished up, I think, with a total staff of about twenty-five or thirty there. We converted the slaughterhouse itself into a little factory and had our machines and so on there. We needed an office and we bought a caravan. Because the gateway through the archway was so small we had to lift this caravan from Middle Way right over and put it down in the yard and then a second caravan, I think. Then we rented some rooms in one of the houses nearby, you know, for the accounts and that sort of thing. There were about twenty-five of us when we were there and when we left Middle Way, we were there, I should think, for about five years.

RR Oh yes. Were you making money at that stage?

MW We made money from year one because all the technology came out of the university, for which there was a return flow at a later date. Because it did, we didn't have the sort of terrific spending years that companies often have nowadays when they start.

RR You were very, very careful.

MW Yes. We made profits in our first year. The Clarendon was marvellous and let us use test equipment and coil winding.

RR Now what about the refrigeration and all that, because the liquid helium, you couldn't get enough helium from the Clarendon, could you?

MW We did in fact. I mean we used the liquid helium from the Clarendon for all our first years, it was quite a problem and we were naturally bottom of the list.

RR Yes, it wasn't a very big machine.

MW It wasn't a big machine and it wasn't very reliable. It was quite busy and we were only allowed to have it on the basis that we took the gas back. Whenever we were testing magnets, my job was usually in a van taking meteorological balloons full of gas back down the Banbury Road to feed back into the system.

RR Because helium gas was very expensive. It was frozen helium in this country. It all came from America.

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MW Expensive and difficult to get, it wasn't just the money. So it was difficult testing magnets. We tested them up there, we had a little test lab in Middle Way, and we did this. You say how did the business grow? Once we had a little publication in the *New Scientist*, they published this very quickly, and requests for magnets came flooding in. There was no competition in Europe at the time, a little bit in America, but I think you could say in a way we have suffered from that. Oxford Instruments has always tended to jump on or recognise some new scientific discovery perhaps and capitalise on this commercially, where you start off perhaps with a 100 per cent of the market and then you come down, but at the time it is so well known scientifically that our customers come to us anyway. Perhaps my colleagues wouldn't like me to say so, but I think we have been better at developing totally new products than we have been at marketing and selling products when say we have only got a small percentage of the market when we are in competition with other experienced firms around the world. I think we are getting much better at that nowadays, but in the earlier days, you know, people trod their paths to our doors.

RR Yes, I see, I understand that. But didn't you start a cryogenic supply?

MW Yes. We soon found that all our customers to begin with had the same difficulties as we had in getting liquid helium. There were only two or three liquefiers in the country. British Oxygen supplied helium, but you had to take your container down from wherever you were in England down to somewhere south of London, taxis across London and all that.

RR I remember doing that, it was dreadful.

MW In the end PL took it over and even that you still had to go there and so on. Then we had the idea of starting what was known as the milk round, it was a helium round, but we bought a liquefier from the States. Audrey always wonders why the bank agreed to lend us the money against the security of the liquefier, and how they did that is extraordinary.

RR It would be difficult to think of something to do with it.

MW Couldn't possibly have sold it. Anyway we got it over and within something like two weeks of it arriving we put out a note saying 'ring up.' We got a young lady with a nice voice on the phone and she telephoned around and said, 'Say what you want,' and I think, 'Within five hours we will have helium in your lab,' and it absolutely transformed the situation. It transformed it psychologically to begin with and then people had to get the equipment and so on, you know, and then they had to apply for money. They suddenly knew that they could, for a very limited budget, have high magnetic fields.

RR And how long did the cryogenics business continue?

MW Well, we had to buy another liquefier in less than a year, a second one, then we started bringing and importing it in very large containers, five thousand litres containers.

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RR By air.

MW That was quite a problem too, because you tend to lose a lot in the handling. And then when we really needed a third one, we came to realise that we were not in the gas business so to speak, and in the end we sold it to Air Products and they took the liquefier and they ran it first of all from here and then took it all.

RR That was obviously a very important development for the company.

MW It sort of...

RR It reassured your customers.

MW Yes. It sort of opened the research into high magnetic fields. People simply couldn't do it before and this was one of the big barriers. It was rather a pleasure, knocking a brick wall down with your head somehow, going right through as they say. You have got to do this, and the only way is to buy a liquefier in doing it, and it was rather fun.

RR Now, at what stage did you move to Osney Mead?

MW When we got the liquefier. When we bought the liquefier we couldn't possibly put that up in Middle Way. We rented an old laundry from the City down where the College of Further Education is now built, in what was called Abbey Road, off Paradise Square, a part which the City pulled down I am afraid. I think it was a bit tragic really, I think there were some beautiful areas around Paradise Square. This was all flattened and is now carparks and CFE and so on. There was a very old laundry there, a lot of the old equipment was there, leaking roof and so on, and we put the liquefier in it and ran the whole of our helium system from this laundry. It had a lot of space, which was an important thing there, and very soon after that we felt we knew we needed more space again and so we bought the boathouse down in Osney Mead. Initially, you could only get there by water, but we got permission to put a road in and put a drive in and have been there ever since. We are still there now.

RR Osney Mead, that was a big turning point really in the company.

MW Yes, it was a big turning point and marvellous to have all the space and so on. I have to admit that our systems, production systems, financial systems were not adequate to be able to cope with a change like that and suddenly a lot of the pressures, the ability to control a firm when it is very small, where you can see everybody practically when you walk in up at Middle Way, that was all relaxed. This was a big place and although it should have been a turning point which we zoomed ahead, we did in a way, but two things happened. First of all, we had trouble with the materials, the superconducting materials, the manufacturers had some problems, and secondly by not doing our cost accounting properly and so on, we got into financial difficulties. So our move to Osney Mead was in one sense marvellous, but actually it was a beginning of several years of pretty rough operations, technically and financially.

RR Yes.

MW Which finished up, and we knew at the end of the day, we were expanding so fast that we couldn't do this on our own, you know, me going to my mother-in-law and asking her if we could have five hundred pounds to pay the wages at the end of the week. A great time that was, but there comes a time...

RR You can't go on doing that.

MW No, we were over-trading grossly and we were getting into bad books with our bank and we started looking for a partner and somebody who could bring in more money. We first of all talked to a couple of companies. Air Products, we looked at IMI, who were making superconductors, and in the end we struck a deal with the forerunner of 3i's, it was actually a firm called TDC, Technical Development Limited, which then became ICFC, Industrial Commercial Finance Corporation, which then became 3i's. We did a deal with them whereby they took something like, 20 per cent of the company in exchange for the order of a hundred thousand pounds, that was a lot of money then. It has turned out to be an extremely good deal for both sides.

RR I am sure it has been for them.

MW They didn't think so to begin with, in fact, looking back on it the people now say 'How on earth did we ever agree to an deal like that?' because not only did they reckon they paid a lot for a small percentage in the company but they got no dividends for I think it was about eighteen years. When we did go public they put it on record at that time as the best investment they had ever made, looked at over a long period of time, but it was a long period.

RR They had the imagination to see this as something that they should take a risk on.

MW They did. At the end of that period, jumping a large chunk of time now, when we went public, they said 'Now our relations have changed and we have got shares in a public company, we are not exactly supporting a private company.' They were very supportive all this time and once a year at the AGM they said, 'Are you thinking about dividends?' And we said, 'No.' The next year went past and it went on like that. When you are a public company it is quite different and they said 'Well our holding in your company will get passed over to a different department and they will deal with it differently.' They, in fact, sold about half their holding, recouped their original cost many, many times over and have remained a very supportive shareholder with the rest of it ever since.

RR Very good.

MW We were on the best of terms.

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RR So we are now coming to the stage when NMR [nuclear magnetic resonance] became interesting.

MW Yes, well you know all about that.

RR NMR depends on strong uniform magnetic fields and the possibility of having these very high magnetic fields became very interesting. That was in the middle sixties or middle-to-late sixties wasn't it?

MW You shouldn't say wasn't it, because you were there!

RR Yes, I am trying to remember when it was.

MW My memory of that was that we were making one-off magnets up until then, special things, professors would write in from all over the world and we would design something specially for them. Then we heard that there was some professor up in the physical chemistry department who wanted a magnet with very high homogeneity, we invited him down or he came down, I don't know, and this gentleman, you, appeared. Weren't you vice-chancellor at the time?

RR No, no. I was Professor of Physical Chemistry then.

MW Well you seemed very important anyway. Right you came down and you told us that you knew how to build homogeneity. There was a Frenchman who was involved in this and who had some special set of coils.

RR Yes, Marcel Golay who is an old friend of mine.

MW Right. You had been told that there was a scruffy little company down the seamy end of town, who could make high fields. I remember you saying that if we could get together we could really do something important, which we didn't understand quite what it was.

RR And I went and got some money from the Research Council to build two magnets, one was to be a model to test the designs and the other was to be a working model.

MW Well to make a short story of the whole thing, looking back on the whole thing that was the beginning of a very exciting period of development in which we, with your help, made a coil which was a higher field, higher homogeneity coil than anywhere else in the world. You took it up to your lab, did work in it which, am I right in saying it sort of put some of the work you were doing on a higher plane than anywhere else in the world?

RR Oh yes, because the field was three times the field which you can make with a magnet.

MW Yes, well right. You were then very generous in giving us a lot of credit for this, and you published this and we got lots of lovely orders from other people for

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them and made profits, so that when you came back, we were able to fund the development of the next magnet. There was a sort of circle that went round like this.

RR Well I think we have just about got to the stage now where the next step really probably was when we had a meeting in my dining-room in Merton College with the Bruker Engineers, to talk about manufacturing a whole lot of magnets for the 270 megahertz systems and I think we have probably reached the stage where this will be a convenient place for us to break, and we will continue after lunch. Does that sound alright?

MW That is fine.