Measurements for the quality of life

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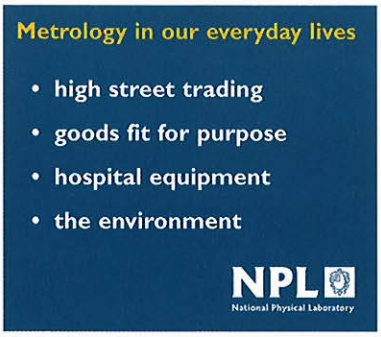
"We have seen how NPL's work to support industry and enhance the quality of life has served the UK well for decades. The demand for our work continues unabated and it is gratifying that the application of science and technology through metrology can so clearly be seen to be influencing economic growth and social progress."

Thank you Mr Chairman. I am pleased that you find the title of my talk to be intriguing. Many people have asked what does *quality of life* really mean. I suppose I can say that your concept of *quality of life* may not be the same as the person sitting next to you. I hope it will become clearer as I go through my talk what I mean by it.

One of the endlessly fascinating aspects of metrology is actually identifying the extent to which measurements of physical and chemical quantities pervade our everyday lives. It is difficult to find an area where measurement does not find some application. And the more you think, the more examples you find. Measurements play a key role in ensuring the efficiency of manufacturing. Components must be manufactured correctly first time to design specifications, otherwise there will be a costly waste of material and the expense of re-machining. A key to the efficiency of manufacturing is the ability of industry to make measurements to the accuracy they need, quickly, *in situ* and at minimum cost. No one wants to pay for measurements but they are very much needed.

But industry is not the only beneficiary of a robust national measurement system. Looking around the room today, when you look at the pictures you will see the portraits of many distinguished Fellows of the Royal Society. Now measurement, undoubtedly, played a major role in their research but measurements in support of science and engineering are not the subject of my presentation today.



In fact, I am going to talk about the impact which measurements make on the well-being of individuals - that's you, me, and everyone. We benefit from a wide range of measurements which every day are carried out in our interest, many of which go unnoticed. When we buy things in shops, for example, we don't want to be cheated. We expect the shopkeepers and traders to provide us with what we think we are buying. For this we depend upon weights and measures legislation and the work of the National Weights and Measures Laboratory together with local trading standards offices. Their activity, legal metrology, depends upon national measurement standards held at NPL.

We as consumers want the confidence that the goods we buy are safe and fit for purpose.

When ill, as patients, we must have confidence in the equipment used in hospital for diagnosis and treatment.

We expect also the air we breathe and the water we drink meet certain standards of safety.

These are all everyday things but you do not often think about their dependence on measurement. Concern for our well-being has led to the government and other authorities introducing directives and regulations which aim to provide goods and services which won't harm us. One can be more positive, in fact, and say that the government actually promotes well-being throughout the nation.

It doesn't just concentrate on regulations and directives. My presentation today is essentially about the so-called quality of life issues, which are precious to all of us as individuals. In most cases, testing needs to be carried out to demonstrate conformance with the appropriate directives and regulations. Tests inevitably depend on measurement and so it is important that the UK has access to measurement standards of an appropriate accuracy. The government determines what is needed and NPL and indeed some other laboratories, such as LGC, develop appropriate measurement facilities and expertise to support the quality of life. In our research programmes, the quality of life falls into the following categories: trade and consumer protection, health and safety, environment, law and order, and defence.

When one looks at NPL's history of activities, it is clear that quality of life issues have been addressed throughout the NPL's 100 years. In fact, quality of life is a fairly modern term that one uses, but if you examine NPL's history, we have been looking at quality of life, or measurements associated with quality of life, from a very early time. And here are some examples that you might be interested to see.

For example, 1913 saw the adoption of the UK's first radium standard. In fact, from 1929 to 1940 it is estimated that NPL tested 20 per cent of the world's supply of radium. In 1921, we started work on acoustics to study the noise from horns, underground trains, and air raid sirens. These were important in those days and acoustics work started on the basis of problems in those areas.

Some key dates in 'quality of life' work at NPL

- **1913** adoption of the UK's first radium standard
- **1921** start of acoustics work
- **1923** study of ventilation in the House of Commons
- **1934** introduction of an X-ray protection service for users
- **1934** lighting for the Tate gallery
- **1935** studies of vehicle noise
- **1943** studies of aircraft noise
- **1944** sound insulation of houses
- **1952** start of Radiological Protection Service
- **1952** studies of the properties of the human ear
- **1972** computer verification of signatures
- **1980** facility for microwave hazard monitors
- **2000** traceable measurements of em radiation from mobile phones
- **2000** radiation doses at high altitudes to air crew and passengers

NPL
National Physical Laboratory

And then in 1923, NPL studied the ventilation in the House of Commons. Here we have a very special example where NPL addressed the quality of life of a highly specific section of society! There was the introduction of an X-ray protection service for users in 1934 and then we go through some other examples. I had a huge number of things to choose from, but these are the ones I have selected hoping to give you a glimpse of the kinds of things we have done: studies of vehicle noise, aircraft engine noise and the start of the Radiological Protection Service which was headed by NPL staff. In 1969, measurement of atmospheric pollution started. It was at the start of Concorde flying and the Americans were very worried about the possible effect of pollution from Concorde. Martin Milton will be talking more about this later this afternoon.

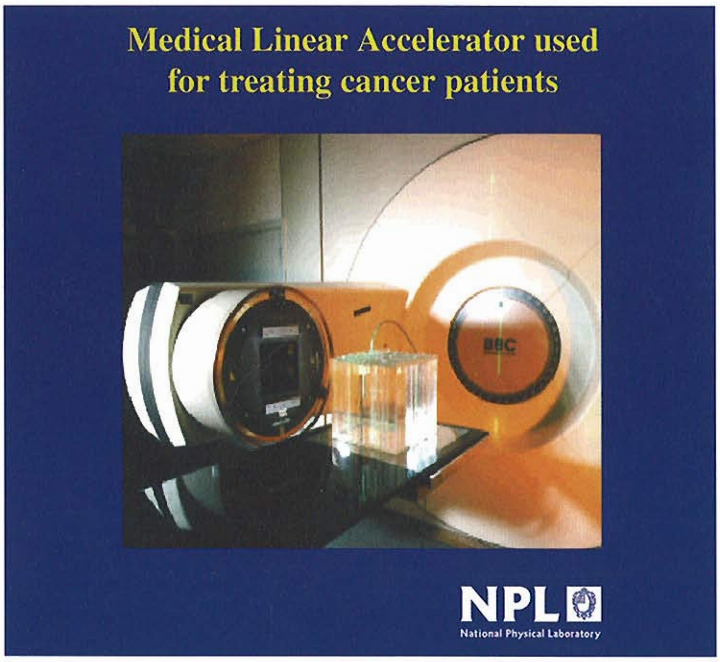
Perhaps something quite different is the computer verification of signatures. This is to do with fraud. The work led to greater peace of mind and, therefore, better quality of life. In this area we are currently working on the authentication of biometric techniques to help us make sure that in the future when you use your cash card in a cash machine there is no problem in its use.

In 1980 a facility was established for testing microwave hazard monitors. If we move to the present day we provide traceable measurements of electromagnetic radiation from mobile phones, which many of you might be concerned about.

All of these activities are stimulated by the needs of society. During the 1920s and 1930s, the general public became increasingly noise conscious. In the 1920s and 1930s, there is no doubt that the problem developed from the growing popularity of broadcasting, the increased mechanisation of the workplace, the intensification of road traffic and the poor sound insulation properties of some of the new building materials. To this day, sources of noise continue to be high on the list of discomforts which consumers endure. In fact I was at a meeting in Brussels the other day and they were saying noise is the issue that is not reducing at any level. It is going to be one of the major problems for the EU to consider. This has led to a wide range of directives and regulations on noise and it is NPL's acoustics facilities and measurement services which ensure that sound levels are correctly measured in the UK.

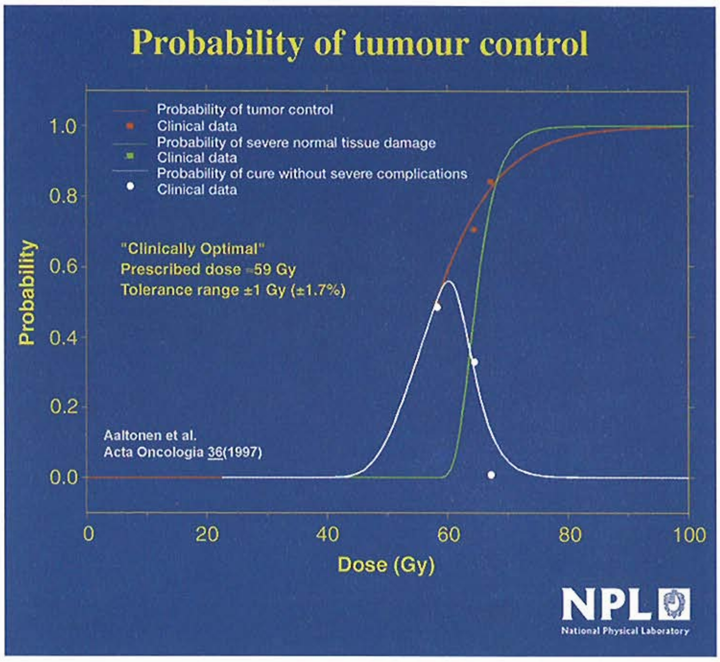
Less immediately obvious, but much more devastating in the longer term, are the effects of ionising radiations. It is important that people working in potentially hazardous areas, where radioactive materials are present, are properly protected. It is also vital that equipment in hospitals used for radiotherapy delivers the correct dose. Too much and you will find that radiation damages healthy tissue and too little and you will find that it doesn't kill the cancerous growths - but more on this later. NPL maintains a wide range of facilities to ensure that it can provide the appropriate measurements services for ionising radiations to afford the protection we need. In recent years, the use of ionising radiations has extended to the sterilisation industry and the treatment of food, which again, is very close to our hearts.

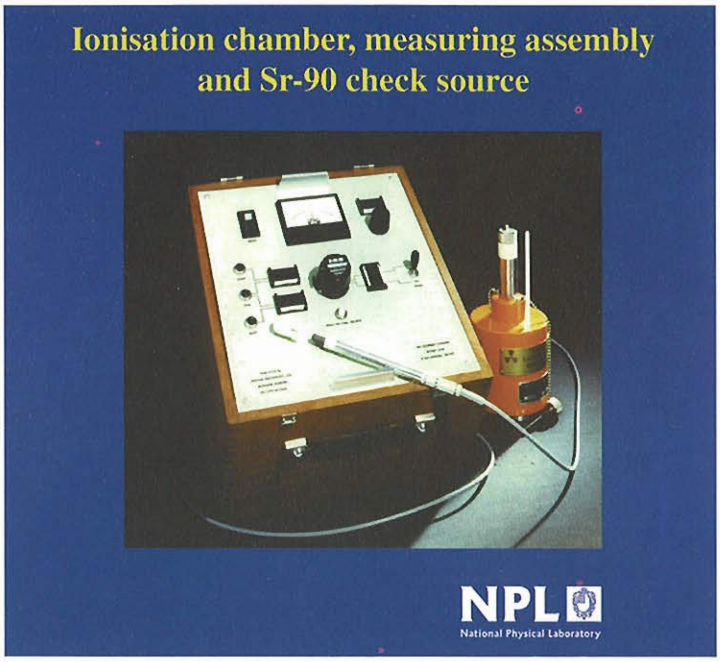
So what I would like to do is to talk about two specific examples of NPL activity which concern our health and safety. Radiotherapy is the first one and ultrasonic diagnosis and treatment is the second one.



Each year, 270,000 new cases of cancer are diagnosed in the UK. Of these, between 150,000 and 200,000 - we are not talking about small numbers, they are very large numbers - will be treated at one of the UK's 60 radiotherapy centres, about two thirds with the intent to cure and the rest to relieve pain and suffering. In radiotherapy, the aim is to deliver a radiation dose to the patient, with X-rays or high energy electrons using equipment of the type shown in the photograph that is sufficient to kill the tumour, as I said previously, but not so high as to produce serious side effects endangering the patient's life.

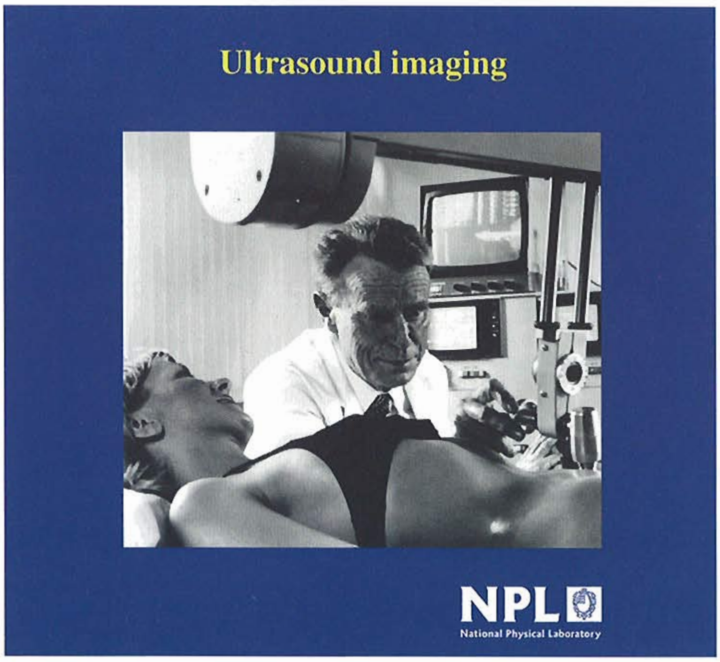
The safe dose window between tumour control and severe normal tissue damage varies greatly but it is generally quite small. For example, in the graph that you have here, taken from a recent study on head and neck tumours, (this is one of the most sensitive areas of the body), the red line shows the probability of tumour control as a function of dose delivered, whereas the green line, shows the probability of severe normal tissue damage. So, what we have is a very small safe window in which you have to get the radiation dose correct to treat the patient. The authors of this study concluded that

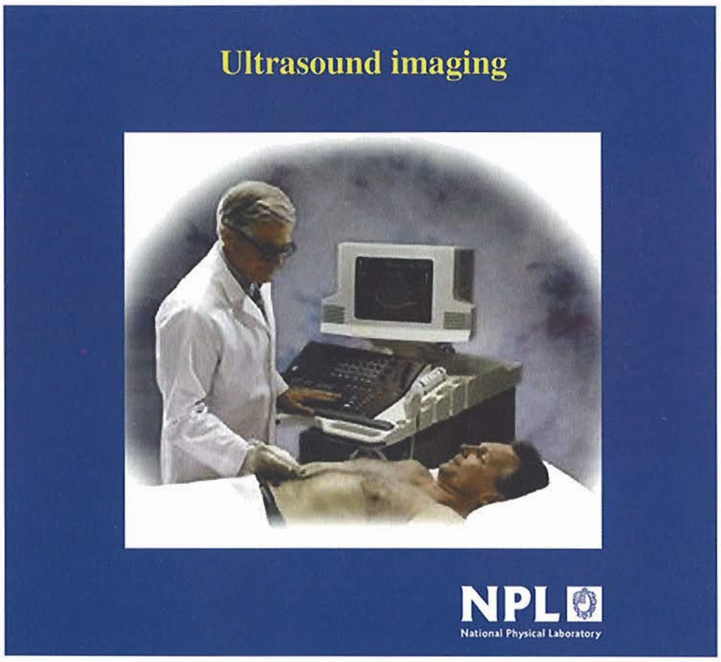




if the dose is delivered with an uncertainty of 3.5%, 10% of the patients (and as I said earlier we are talking about quite a significant number of people here), who could potentially be cured, would die. Now if you can reduce the uncertainty to 1.7% from 3.5%, you would dramatically increase the survival rates. In fact, the death rate would be halved.

However, measuring dose is difficult. The primary standards for X-rays and high energy electrons themselves have uncertainties of around 1%. Due to the technical difficulty of making such measurements, we have real issues in terms of producing standards for radiation dose to water, which is the quantity that needs to be measured in radiotherapy. NPL has readily worked in overcoming these problems and calibrating the instruments used in UK hospitals to ensure dose delivery is as accurate as possible. We collaborate with the Institute of Physics in Medicine and Biology to audit UK radiotherapy treatment centres. Each centre has an ionisation chamber like the one in the photograph which is calibrated in terms of the absorbed dose to water at NPL at least once every three years. Until 1990 this was always done by calibrating against a standard for a relative quantity called air kerma and then carrying out a conversion to absorbed dose. This procedure introduced significant uncertainty. In 1990, NPL launched the world's first service directly calibrating such radiotherapy reference instruments in terms of dose to water for X-ray radiotherapy. This reduced the uncertainty of calibration by about a factor of 2 from 3% to 1.5%. This was followed in 1998 by the launch of the world's first such service for high-energy electron radiotherapy, in this case reducing the uncertainty of calibration by a factor of 3 from 4.5% to 1.5%. And we haven't stopped there. We are now working on a new primary standard actually based on water which, it is hoped, will reduce the uncertainties even further. To achieve this, we are looking to detect temperature changes of the order of microkelvins in a water calorimeter with an accuracy of nanokelvins. There are many factors which determine cancer survival rates. But we are working to ensure that UK cancer patient treatments are based on the most accurate dose measurements in the world.

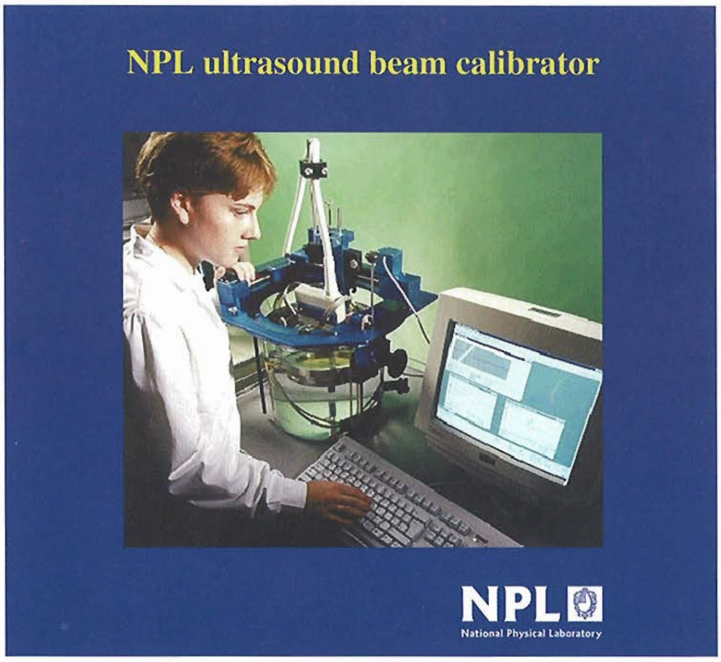


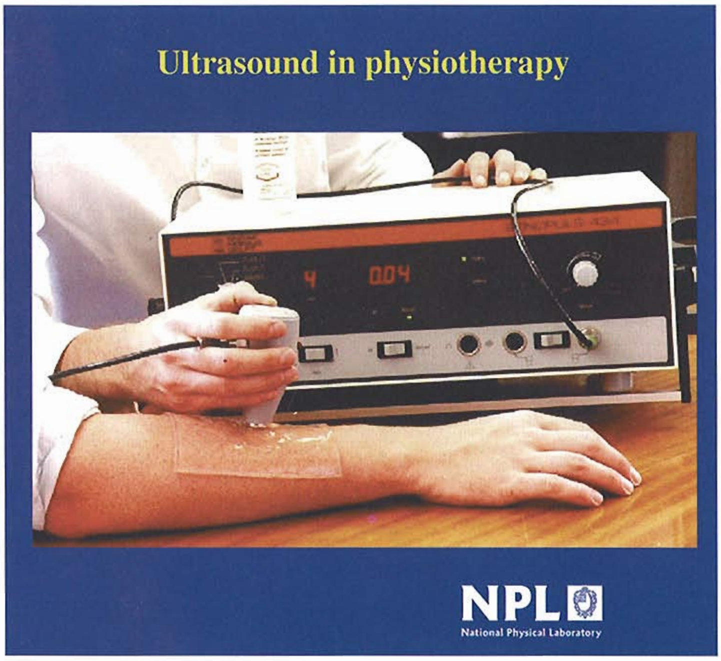


Now I would like to move to the ultrasound case. This is another very good example because ultrasound is used in clinical treatments, both in diagnosis and treatment of patients. And in ultrasound therapy there are more than one million treatments per year, with the potential to overheat tissue and bone. Here is an example of some equipment from the 1960s. Those of you who are familiar with this kind of equipment will want to note its size. NPL was the first laboratory in Europe in the late 1970s and early 1980s to measure reliably the acoustic output of ultrasonic transducers. At that time, the only parallel work in the world was that of the US Food and Drug Administration. We were able to show for the first time that the acoustic pressures generated were very high - not an atmosphere of two, but many in fact - and that the wave forms were unexpectedly distorted from sinusoids to a saw tooth profile. We soon understood this phenomenon was caused by non-linear propagation effects.

The safety of diagnostic ultrasound has always been a vital issue, particularly so, as the majority of clinical applications of ultrasound are in obstetrics and other critical clinical sites. Ultrasonic beams of very high acoustic pressure, (which can be in excess of 10 MPa) and relatively high power levels (which may be fractions of a watt) focused on to small volumes of tissue can be very hazardous. Work at NPL has shown that temperature rises *in vitro* can approach 10 °C. We have made major contributions to all the necessary underpinning work to ensure the safe use of ultrasound.

Over the years, the technical measurement problems in ultrasound have grown and become quite substantial, requiring a high level of innovation at NPL. Here we can see a typical modern scanner used both for imaging tissue and for measuring blood flow. You can see that the size of the equipment has actually gone down. The ultrasonic beams generated are amazingly complex and involve sequences with dynamic focusing, mixed pulse types, and virtually all in real time, using phased linear arrays. To keep up with the need to separate out these pulses and to be able to characterise and measure the acoustic output of these complex systems needed to meet regulatory requirements, we have developed an ultrasound beam calibrator, which we can see in the photograph. This system has been extensively used for projects for the Department of Health, which are aimed at ensuring the continued safe use of diagnostic ultrasound.





The next photograph shows an ultrasound system used in physiotherapy. Here, high power ultrasonic levels are used for the treatment of soft tissue. NPL has developed methods of measuring the acoustic output of these systems and characterising the quality of the acoustic beam. As in the case of diagnostic ultrasound, this work contributes to ensuring the quality of clinical treatment. So, ladies and gentlemen, our ultrasound work contributes to the quality of human life from the foetus to the adult.

I have chosen just two examples of NPL's activities which demonstrate how our work has supported the quality of life. There is a very rich collection of such examples. In fact I was spoiled for choice. But I hope, nevertheless, that I have been able to persuade you that NPL has applied and continues to apply world-class science to the solution of problems, which if not resolved, would have detrimentally affected the quality of our everyday lives.

This is the last presentation of the morning session and I would just like to conclude by saying that we have seen how NPL's work to support industry and enhance the quality of life has served the UK well for decades. The demand for our work continues unabated and it is gratifying that the application of science and technology through metrology can so clearly be seen to be influencing economic growth and social progress. «

Dr Peter Briggs (chairman)

Dr Hossain, thank you for rounding up the morning in such a splendid way and showing us how the work of NPL impacts on the lives of all of us in so many ways. I couldn't help thinking, as we listened to the talks, how those members of the British Association back at the end of the 19th century who lobbied so hard for the foundation of NPL would be delighted and amazed to be here today and to see what enormous achievements the creature they helped to put into place has made in the last hundred years. So thank you to the three speakers in the second session.