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CENTRES OF RESEARCH
No. 11.

Producer: Bob Axworthy

OPENING ANNOUNCEMENT:

BBC World Service - Centres of Research.

In this series of programmes Norman Dahl visits each week a specialised centre of research in Britain. Today we go to Waltham Abbey, Essex to the Explosives Research and Development Establishment.

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DAHL: The site of the Explosives Research and Development Establishment at Waltham Abbey near London has been connected with explosives for hundreds of years. The first official record of a gunpowder factory there dates back to 1561, but it had certainly been going before then. During the Napoleonic Wars they produced 25,000 barrels of gunpowder a year, and during both the World Wars they were a major producer of cordite and high explosives. Today the site is largely quiet woodlands, dotted with small, empty huts set in earth bunkers, because it is no longer a place where explosives are made in bulk. It's now become an experimental station with only pilot plant production facilities. 'Explosives' of course, is an emotional word conjuring up images of war and death. This isn't entirely fair, because they are no more than concentrated stores of enormous energy, that can be released for good purposes as well as bad. High Explosives are used in mining and quarrying; rocket propellants operate ejector seats and life-saving rockets as well as missiles. Nevertheless, the Explosive Research and Development Establishment's biggest customer is the military. The title is not/particularly accurate one now, because the Establishment does a great number of other things besides. About 20% of the total effort goes on explosives. As the Director, Dr. L.J. Bellamy explained to me, the reason is that there is no longer any need to look for more powerful explosives.

BELLAMY: We have no objectives to produce more powerful explosives; we are only concerned with safer explosives, more reliable explosives and special needs for special purposes like lower costing explosives which are extremely cheap and you generate them on the site. These are becoming industrially important in mining and they may well have military uses and we move into this area and do some work into this field to see how cheap and effective we can make them.

DAHL: About half the laboratory's research effort is devoted to solid rocket propellants. Cordite, the propellant used in guns, has been used for rockets, but it has a number of disadvantages. Chief among these is its brittle nature. Put in a rocket case, it will contract and expand under changes of temperature at a different rate to the case itself. This could well cause it to crack, which would be disastrous for the rocket when it's fired, and also probably for the person firing it. The head of one of the Establishment's two propellant divisions, Mr. P.R. Freeman, describes the solution to this problem.

FREEMAN: This means, in effect, that we need rocket propellants which are extremely deformable: either rubbers or stiff paste rather similar to modelling clay. This type of propellant is normally obtained by using a polymeric liquid or rubber and mixing with this liquid or rubber sufficient oxidizing material and the most powerful oxidizing material we have come across which can be used is ammonium dichlorate mixing sufficient of this oxidizing material to get complete combustion of the polymer. To get complete combustion, something close to 90% by weight of ammonium dichlorate is necessary and this makes it very difficult indeed to retain physical properties which are characteristic of the liquid fuel component, in other words the plastic or rubbery characteristics.

DAHL: To make a rubber stay rubbery when it is filled with so much

DAHL: solid filler is a very fine chemical achievement, and one likely to have an important application in straightforward rubber technology. A great deal of the work done at Waltham Abbey, even when directly commissioned by the military, has at least potential value in industry. Explosives, after all, are only chemicals - with unusual and dangerous properties, to be sure, but chemicals none the less. The laboratory is very conscious of the contributions it can and does make to industry. About a third of the laboratory's work has nothing to do with explosives at all. It's mostly concerned with various forms of material, and includes some fundamental research work that is either too dangerous or unsuitable for a university to undertake. Dr. David Richards works on polymers - the long-chain molecules that are the basis of rubbers and plastics. His research began several years ago on a post-doctoral fellowship under Professor Schwartz in the United States, and he's now developed ways of making a whole new range of plastic materials. Dr. Richards.

RICHARDS: The technique which Schwartz developed is known as the 'living polymer' technique and this is an organo-metallic process and therefore the whole field which we are developing is in the field of organo-metallic chemistry. By counting out certain adaptations of this basic technique of the living polymer system, we are able to arrange the polymer molecule in a specific manner, in other words we able to make what is known as regular copolymers. One example of this would be polystyrene, a hard, brittle material and polythene, a soft material. And you may want to make a material which has some of the properties of both these separate polymers. You can't do it by mixing because they don't like each other and they would separate in different phases and whole system crack, and therefore you have to build in the two components styrene and ethylene , and in this case, you have to build these two components into the one chain chemically. A technique which we have developed enable us to do just that, and therefore we are able to produce materials which have properties which vary between these two extremes.

DAHL: And Dr. Richards has found, more or less by accident, that his work can also be applied to the smaller molecules of ordinary chemistry.

RICHARDS: We've inadvertently come across a method for carrying out the reaction which is well-known in straight chemistry- the Grignard reaction, and if anybody has ever worked in chemistry, they will have learned about this technique. It's a method which was developed at the turn of the century and is a two-stage process. In other words, what you do is, you make first of all what is known as a Grignard reagent and then use that Grignard reagent to react to the second ingredient to produce the product you require. Well, we were experimenting in a different field and we came across a one-stage process for carrying out this particular action, so that now you can take the reactants, carry out the specific reaction with them and the products fall out at the other end. So you have a one-stage process as against a two-stage process. Also it turns out fortunately that the yields of the products you get are in the majority of cases quite lot superior to that given by the conventional Grignard process.

DAHL: This brand new development could be very interesting to, for example, the pharmaceutical industry to produce higher alcohols at a fraction of their former price. Another very active field of materials research is composite materials - where fibres of/very strong material are bound together in a matrix of metal or resin to give a final result better than the two components separately. Glass-fibre reinforced plastic is an everyday example, and the immensely strong carbon-fibre material developed by Rolls-Royce is another. Ordinary carbon fibre material is made with long fibres, but the approach at Waltham Abbey is different; they're interested in short fibres - needle-like crystals of ceramic materials such as silicon carbide or silicon nitride, known as whiskers.- or other short fibres. Mr. Hans Ziebland is in charge of this work.

ZIEBLAND: One of the essential prerequisites of using whiskers for instance, is that the fibres can be graded and it's perhaps less well-known that in order to utilize whiskers or any fibrous materials for reinforcement effectively, a minimum length to diameter ratio is needed, which varies of course with the type of matrix which is employed. In general, the useful whiskers begin at about an aspect ratio of between 20 and 50 for metals and they go as high as 500 for plastic materials. Now processes for this type of sorting and grading have been developed, and they were absolutely essential. Of course it was necessary or rather an essential consequence to look around and see where else such processes would be useful. After, all nature has given us not only whiskers which we have to grow ourselves, of course, from complicated processes, but also of course a lot of mineral material which appears in nature as a whisker-like mineral such as asbestos. It was natural, of course, that one went a step further and looked for the ultra-strong fibres, that is to say the carbon fibres, which have received so much publicity. And although carbon fibres are nowadays produced by a continuous process, we went the other way, we chopped them, we chopped them into short-length fibres of one to two millimeters total length, and aligned these fibres and made composites out of these fibres to prove that composites made from short fibres give us approximately 90% of the modulus and between 70 and 80% of the maximum tensile strengths that is obtainable from continuous fibre composites.

DAHL: The problems of developing short fibre composite materials are indeed formidable. The growing of ceramic whiskers is still not fully understood; the fibres, whatever they are, have to be graded, as Mr. Ziebland explained. And then they have to be lined up in the composite so as to give strength in the direction it's needed, and the laboratory has produced a pilot plant that can do this, and even line up the fibres in curves or circles if this is necessary. The remarkable feature about these composites, apart from their strength and lightness, is that they're anisotropic -that is, they behave differently depending on the direction of the stress. Wood is anisotropic, because it has a grain; steel, on the other hand, is isotropic. As Mr. Ziebland says, this opens up a whole new world for the design engineer.

ZIEBLAND: We are at the beginning of what I think is a kind of materials revolution. We have in the past been concerned

ZIEBLAND: with isotropic materials engineering and construction. I forget conveniently about wood of course which was one of the earlier materials which engineers used, but since then of course we have used almost exclusively isotropic materials. If one uses high strength materials, reinforced for instance, the entire production technology will have to change. One does not need high strength material where there is no high stress. And in consequence, of course, reinforcement could be confined to those areas where high stress exists, where we know it exists, and the rest can be filled with some inexpensive material. It could be glass fibre, it could be asbestos.

DAHL: Essentially, then the Explosives Research and Development Establishment is one of Britain's most advanced applied chemistry laboratories, with some valuable fundamental work thrown in for good measure. But by the nature of their work, they handle every day highly dangerous materials and do experiments that could literally blow up in their faces. I asked the Director, Dr. Bellamy, about safety.

BELLAMY: If you know what you're doing, it's a remarkably safe occupation, and the safety record is a lot better than general chemical industry as a whole. When working on a new explosive, the material is first assessed for its explosive power and is then put in a cupboard with a limit of weight which is allowed in the cupboard. If that whole weight explodes, it will stay inside the cupboard. So as long as you observe the rules and as long as you remain slightly scared, you'll remain safe. And to ensure people remain slightly scared, we lay on the regular demonstrations of explosions and flying glass and things of this sort to make quite sure people are aware of the hazards.

DAHL: And in conclusion, I asked Dr. Richards, whose polymer work also involves dangerous chemicals, if the laboratory's experience with such things was helpful in his work, which has nothing to do with explosives as such.

RICHARDS: Yes, I think it's an advantage in a wider sense than this because here I am allowed to do what one could call long-term research, that is research which may take a period of six months a year or even two or three years to reach a conclusion. And that in conclusion could well be an unsuccessful conclusion as well as a successful one, but I think that the main advantage is in this fact that I am allowed to relax and think up ideas which have not got to be immediately transferred into product. And it's a very, very relaxing atmosphere and I think a very fertile atmosphere to work in.

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