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NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

GOVERNING BOARD

HIGH FLUX NEUTRON SOURCE

Covering Note by the Secretary

It was reported at the Board meeting on 22nd September, 1964 (Minute 2.4) that a meeting of potential users of a high flux thermal neutron source was held on 3rd July, 1964, and that an account of the meeting would be submitted to the Board. This account has now been prepared and a copy is enclosed.

NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

MEETING ON HIGH FLUX THERMAL NEUTRON SOURCE

1. INTRODUCTION

A meeting took place at the Rutherford High Energy Laboratory on 3rd July, 1964, to discuss the provision of a high flux thermal neutron source in the U.K. Papers were presented by Dr. Lomer, Dr. Vick and Professor Mitchell. Participants included neutron users from a number of universities and the U.K.A.E.A. (see Appendix I).

2. CHAIRMAN'S OPENING REMARKS - SIR JOHN COCKCROFT

Sir John stated that the object of the meeting was to enable the case for providing a thermal neutron source in the U.K. with a flux an order of magnitude higher than that now available from the Harwell reactors Dido and Pluto, to be prepared and studied. The history of the project started about 1961 when Harwell investigated the design of a high flux beam reactor. It became a project of the European Nuclear Energy Agency but, about a year ago, the E.N.E.A. decided, for budgetary and other easons, to shelve the project for two years. The question was then raised whether we should revive the high flux beam reactor purely as a U.K. project. The next development was an alternative proposal for a pulsed neutron source at Harwell based on experience gained on the neutron booster.

Neutron users present at the meeting were invited to state their views on the need for a high flux neutron source and on the type of source they would prefer.

3. NEUTRON RESEARCH - DR. LOMER

Dr. Lomer presented a paper on some significant advances so far made, or foreseeable, with neutron techniques. It covered work on antiferromagnetism, spin exchange couplings in solids (the most direct evidence of co-valency), the non spherical nature of spin distribution (the best evidence on the nature of the wave-function of valence electrons) and magnetic defects in ferromagnetic alloys. This work was relevant to both physics and chemistry.

Investigations on the atomic distribution in solids enable hydrogen atom positions to be determined and atoms of similar atomic number can be distinguished. In future biological studies might become possible. Imperfections in crystals was a fruitful field of neutron research, but for crystallography on perfect crystals X-ray work was usually simpler. Neutrons could have advantages in certain systems for many of the heavier elements. Inelastic studies allowed precisely defined experiments on phonons and spin waves to be carried out. Analogous effects in magnetism were giving information on the range of magnetic interactions in crystals. Work on the dynamics of atomic motion in solids and liquids produced clearer results than other techniques. The fact that velocity correlations as well as spatialcorrelations can be determined was changing the qualitive approach to the theory of liquids.

All these branches were very active. With the detailed and unambiguous nature of the results from neutrons, very considerable advances had been started. But the rate of work was slow because existing reactor fluxes made experiments slow to do and demanded large crystals which were hard to make and which introduced serious technical difficulties of interpretation.

4. TYPES OF NEUTRON SOURCE - DR. VICK

Dr. Vick opened by announcing the formation of a study group to bring together the opinions of the neutron users and the people concerned with the design of neutron sources to decide how to formulate recommendations to be put to the Government. The study group would be representative of the various interests concerned. Terms of reference had been proposed and the constitution of the study group was being worked out.

Dr. Vick presented a paper on the types of high flux neutron source. The paper summarised the design study of a 70 MW High Flux Beam Reactor. This would have about 23 beam hole positions of which 20 would give fluxes of the order of 10^{15} n cm^{-2} sec^{-1}, on present calculations, with a range of neutron wavelengths. The reactor was designed primarily for neutron beam users and though there might be possibilities for a small number of in-core experimental holes inside the hollow fuel elements for radiation damage experiments, this would definitely be secondary to the provision of neutron beams. The techniques involved were not very far extended from present practice. There might be further work to optimise the design but reasonable predictions could be given as to performance.

The second part of the paper set out the performance and experience with the present booster at Harwell and examined the possibilities of a pulsed super booster for which a design study was under way. A range of possibilities camefrom an enlarged version of the present booster, and Dr. Vick invited the views of the neutron users on how far it was worth pursuing this design, remembering that this was a pulsed source as compared with the continuous source of the reactor and that the number of available beam hole positions would be reduced. (A later comment by Dr. Poole put the number of beam holes at between 6 and 10). The cost would depend very much upon the degree of complexity demanded of the source and in the limit there were problems, particularly engineering ones, which had not yet been solved in detail.

The possibility of improving either Dido or Pluto as a source of thermal neutrons by increasing its power to 25 MW or above had been considered. It would require a good deal of reconstruction of the reactor and might mean putting it out of commission for something of the order of a year. Both the reactors were now fully engaged and some experiments should be continued for a long time. There were possibilities using accelerators for the production of neutrons (apart from the booster techniques) and it might be advisable to look at some of these again in the light of recent developments on accelerators.

5. USER REQUIREMENTS - PROFESSOR MITCHELL

Professor Mitchell presented a paper on the scale and nature of neutron user requirements. He identified two important questions. (i) Is there a sufficiently strong body of opinion in favour of it to justify a request for a neutron source costing of the order of £5M? and (ii) If so, should it be a reactor or a pulsed source?

Dealing with the first question, Professor Mitchell said that it was necessary both to assess whether the physics justified such an expenditure and also whether there would be a sufficient number of University people wishing to use it when it was built.

With regard to the physics, Professor Mitchell's paper gave details of the work being carried out in the various areas of crystallographic studies, dynamic studies and defect scattering. Without some type of high flux source it was unlikely that any of the 'front line' experiments in these fields in the future would be carried out by U.K. scientists. This was the first proposal of this magnitude, as far as the Universities were concerned, in a non-nuclear physics area.

It was difficult to estimate how many people might want to use the neutron source in five years time but reasonable minimum figures were 25 from the U.K.A.E.A. and 25 from the Universities. An unknown factor was the extent of participation from the crystallographers, of whom there were an estimated 400 in the U.K. The effective University number could therefore be much greater. Making allowance for this, the facility would provide neutrons for a minimum number of 60 users. About 75 people had attended the three one-day conferences on neutron research during the past two years which was a further indication of the interest. Professor Mitchell concluded that a case existed for providing a high flux thermal neutron source both from the point of view of physics and the number of users.

On the second question, Professor Mitchell said that a working party under his Chairmanship was looking into the reactor versus pulsed source from the user's point of view, but no clear cut answer had emerged so far.

6. GENERAL DISCUSSION

a) Areas of Neutron Research.

Dr. Arndt - biology. The fluxes anticipated in a high flux beam reactor were a factor of 50 down on standard X-ray fluxes but larger crystals could be used so that neutron beam research would not involve a radical change of technique. In five years time, interest might move to larger proteins beyond the scope of X-ray work, but in the immediate future exciting results were not anticipated from neutron research.

Professor Bacon - magnetism. It was difficult to over-emphasis the contribution made to magnetism by neutron research. This contribution could be seen in stages corresponding to increases in neutron flux. Speaking generally, in all the areas covered by neutron research, people were only just reaching the stage where they could think of using neutron methods to solve their problems.

Dr. Egelstaff - inelastic scattering. Neutron research could make a very real and large contributuon to the theory of liquids. A great deal of work remained to be done which could be instrumental in building up a future theory of liquids. In the chemical field, recent work on liquid crystals and clathrates was opening a new field of research. Another field was that of non-crystallised solids where virtually no work had been done. Many other areas of physics could be named where an extension of existing knowledge, which could lead to a breakthrough, was possible with neutrons.

Professor Anderson.- crystal defects. Present work covered the location of light atoms, the exact nature of lattice imperfections including studies of hydride and oxide systems, nitrides, carbides and the heavy elements. These were relevant to the development of general solid state chemistry or chemistry physics.

Professor Wilson. Neutron diffraction work to find hydrogen atoms or hydrogen bonds was not possible with the highest fluxes under consideration, using the same size of crystal as in present X-ray difraction work. But the gap was not as great as he had anticipated before this meeting.

Dr. Macfarlane. A high flux neutron source in this country would be very welcome. Previously, to obtain some critical results, use had to be made of a reactor in Canada. The possibility of increasing phonon lifetimes in materials was very interesting and could affect optical and electrical properties to produce devices with remarkable properties. Any opportunity of prgoress by neutron studies would be of great practical consequence.

Professor Ball - metallurgy. Looking ahead five years neutron research would be important in metallurgy. Work could be done on liquematic solutions and superconductivity would also require the sort of technique that would come from the use of neutron beams.

Professor Mitchell. Neutron research would make possible substantial advances in every area of the physics or condensed matter that could be considered.

b) Choice of Source

Sir John Cockcroft.

With the super-booster A.E.R.E. would require about half the beam holes leaving only about three for University use. This did not seem sufficient to meet the needs of the number of users forecast by Professor Mitchell.

Professor Bacon. It would be a retrograde step to delay provision of a high flux reactor which was in the natural line of progress and where techniques were already established. From the point of view of structural and magnetic crystallography, new techniques would need to be developed to use a pulsed source.

Dr. Cochran. It would be difficult to use existing equipment and techniques with a pulsed source. There were many more uncertainties connected with the development of a pulsed source, which in any case would take longer to build.

Dr. Egelstaff. The neutron source was needed as soon as possible. Three high flux reactors were already under construction in the U.S.A. Since a reactor would take five years to build, U.K. scientists would lose heart unless immediate action was taken. Rival schools in Europe and America would make headway at our expense because we lacked the source we had requested for a number of years.

It would be wise to pursue both types of source. A pulsed source, from a super booster or an accelerator, might be the more prolific source of neutrons for the future but development on them should go in parallel with a cheaper and more immediate scheme for a high flux reactor.

Professor Anderson. Provision of a facility, such as a high flux reactor, was desirable, not at a distant date, but as soon as possible.

c) Supporting Facilities.

Professor Franks. Design work on data collection apparatus should be pursued as soon as the type of source was settled. If a pulsed source was chosen it would take more development time to use it efficiently and work on the experimental apparatus should not be delayed until the source was operating.

Dr. Arndt. It had been estimated that to develop the techniques and the equipment to use a pulsed source, using the whole of the white spectrum might take of the order of 50 man-years.

Dr. Squires. Generous computer facilities would be needed in conjunction with the neutron source for data analysis.

d) Debate on Costs

During the discussion it emerged that the original estimate for the capital cost of the high flux beam reactor was £10M with an annual operating cost of £2M. However, the estimate had been made on the basis of building the reactor on a virgin site. The cost of the reactor itself was £3M, the remainder being for supporting services. The cost of the super-booster had been estimated at £2.5M, if it were built at A.E.R.E. The importance of comparing like with like on the matter of relative costs was pointed out by several speakers. However, present indications were that when that was done the super-booster would not turn out to be very much cheaper than the reactor.

Dr. Macfarlane. On the basis of the projected number of neutron users in Professor Mitchell's paper and on the cost estimates, the project would cost of the order of £50,000 per user per year. It was open to question whether this was justifiable. Either the facility ought to accommodate more users or a more co-operative effort ought to be made to reduce the figure. If this amount of money was to be made available, a careful debate was needed before assigning it to a comparatively small group of people, comparing its effect if it were distributed among 100 physics and chemistry departments.

Professor Bleaney. There was apparently no mechanism in this country to consider questions of this kind. If some other Body were to assess whether a sum of this magnitude would be better spent on this project or on supporting University technological physics the answer might be very different.

Sir John Cockcroft. The object of the Trend Report was to set up such a mechanism.

Dr. Pickavance. The quoted figure of 60 interested users in five years seemed to be extremely pessimistic. This would have a direct bearing on the cost question.

Professor Mitchell. The quoted figure in the paper was a count of the near certainties and he had not speculated on what the figure might become.

Professor Wilson The number of crystallographers who would use the neutron source would depend entirely upon how easy it was to use. If it should approach anything like the case of using, for example, the Weissenberg camera, the predicted figure of 10 crystallographers would be a gross underestimate.

7. <u>SUMMARY - SIR JOHN COCKCROFT</u>.

Sir John said that the scientific case for a neutron facility had been presented. The discussion had emphasised the users' requirement for high flux beams of neutrons as soon as possible. The immediate need was for a high flux beam reactor in the U.K. while development of a pulsed source proceeded as a long term project. As an interim measure, enquiries would also be made by the N.I.R.N.S. to see whether University staff could use the Dutch high flux beam reactor.

The importance of obtaining funds and technicians for producing the equipment to support the research work on a U.K. reactor had been stressed. The cost of the project per research worker had been brought out byt the number of users quoted was probably an underestimate. Sir John also drew attention to the fact that the University numbers were likely to double in the next decade and the cost of University research to increase by £30 M per year. There would be many more research workers who would need facilities for advanced work. The cost should therefore be assed against this background.

J.M. Valentine,
Rutherford High Energy Laboratory,
Chilton,
Didcot,
Berkshire.

<u>30th September, 1964</u>.

Appendix I

List of Participants

Professor J.S. Anderson	Department of Chemistry University of Oxford
Dr. U.W. Arndt	Laboratory of Molecular Biology Medical Research Council, Cambridge.
Professor G.E. Bacon	Department of Physics, University of Sheffield
Professor J.G. Ball	Imperial College of Science and Technology
Professor B. Bleaney	Department of Physics University of Oxford
Dr. W. Cochran	Department of Physics University of Cambridge
Sir John Cockcroft	Churchill College, Cambridge
Dr. P.A. Egelstaff	A.E.R.E.
Professor F.C. Frank	Department of Physics University of Bristol
Professor J. Irving	Department of Natural Philosophy Royal College of Science and Technology, Glasgow
Dr. W.M. Lomer	A.E.R.E.
Dr. G.G. MacFarlane	Radar Research Establishment Ministry of Aviation
Professor E.W. Mitchell	J.J. Thomson Physical Laboratory University of Reading
Professor P.B. Moon	Department of Physics University of Birmingham
Dr. D.C. Phillips	Royal Institution
Dr. T.G. Pickavance	N.I.R.N.S.
Dr. M.J. Poole	A.E.R.E.
Dr. G.L. Squires	Department of Physics University of Cambridge
Dr. J.M. Valentine	N.I.R.N.S.
Dr. F.A. Vick	A.E.A.
Professor A.J.C. Wilson	Department of Physics University College, Cardiff
Dr. H.W. Wilson	Scottish Universities Research Reactor Centre
Dr. G.A.P. Wyllie	Department of Physics University of Glasgow