

ISMA* Joint Technical and Agricultural Meeting

Lausanne, Switzerland
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**In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).*

THE INTERNATIONAL SUPERPHOSPHATE MANUFACTURERS' ASSOCIATION

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JOINT TECHNICAL-AGRONOMIC CONFERENCE

LAUSANNE: 24th-26th September, 1956.

Report of Discussions

Morning Session 24th September, 1956

In the Chair: Mr. D. J. BIRD.

Mr. GRANDGEORGE, President, (France) (Interpretation): Gentlemen: Once again we are holding our meetings in the month of September; two years ago the Agronomic meetings took place in Bordeaux, and in 1955 the technicians met in Aarhus. Those present at each of these meetings will remember the occasions very distinctly so that there is no need for me to remind you of the details; but it is Mr. Bird's initiative which has brought about these Joint Technical-Agronomic Meetings. We are beginning these meetings with this Conference at Lausanne, and in the name of the Association I should like to thank Mr. Bird for initiating these meetings which, I believe, will be very valuable in the development of the superphosphate industry. Indeed it is not always easy to mix the work of technicians and agronomists in the same working session, but the fact that Mr. Bird is the President of the Joint Technical-Agronomic Committee ensures its certain success.

There are two days of working sessions, separated by a whole day agronomic excursion, and this is a very pleasant programme in a country like Switzerland, which is so hospitable. I know that you will all be most interested in the work and that you are not afraid of difficult problems of modern physics, as I see from your programme that one of your sections deals with the action of isotopes and with the problems which these powerful new methods bring to those interested in physical problems.

I hope, therefore, that your work will be profitable and I am certain that the conclusions you draw will be very useful to members of our Association for the development of our industry. Being neither technician nor agronomist, I am going to ask Mr. Bird to preside, convinced that under his chairmanship your work will progress in a most pleasant and interesting way and that your conclusions will be beneficial. (Applause).

The CHAIRMAN: Mr. President and Gentlemen, first of all I should like to thank you very much for the kind reference which you made to my part in this idea of a joint conference of agronomists and technicians.

On behalf of the delegates, Sir, I should like to thank you for your presence here today. All of us know that you are a very busy man indeed, and your being here is a great encouragement to myself, to the Chairmen of the Agricultural and the Technical Committees, and to the delegates.

I am sure the delegates would also wish me to convey to you, Sir, our very sincere and hearty congratulations upon your recent appointment as an Officer of the Legion of Honour.

Gentlemen, I am sure you would wish me, on your behalf, to congratulate Mr. Marville on his recovery from his recent very severe illness. Although he is not going to take too active a part in our discussions, because both his doctor and his very charming wife have forbidden him to do so, we are delighted to have him with us.

The President in his address made some brief reference to the reason for this Conference. It is true that I made the original suggestion to the Council, but I think it is the Council who must take the credit for having taken the decision. It arose from the fact that when I attended, during my term of office, conferences of the technicians and the agronomists, it was clear that on a number of occasions points arose which could only be answered by the opposite side: in other words, in some of the agronomic discussions it was quite clear that the answer lay with the technicians, and at the meetings of technicians it was quite clear that before they could take a decision they would have to have the advice and opinion of the agronomists.

I think it is encouraging that at the first Joint Conference we have got some seventy workers, and if we include the charming ladies the total number present is over 110.

We also have four guests whom I should like to welcome in your name: Mr. Arnold of the Union des Syndicats Agricoles Romands; Mr. Gisiger of the Station federale d'essais et de Recherche; Mr. Shantz from Canadian Chemical Industries; and Mr. Soubies of the Station de Recherche Agronomique at Toulouse. You will remember, Gentlemen, that after our agricultural conference at Bordeaux some of us went on down to Toulouse and visited the works of the "Office National Industriel de l'Azote" and its Research Station of which Mr. Soubies is the director.

As Chairman of this Conference, I do wish to thank most sincerely Mr. Marville and his Committee and Mr. Stevinius-Nielsen and his Committee for all the work which they have done in advance of this reunion. They have selected the speakers and arranged to get the papers. I am most grateful to them and also to Mr. Charliers and the Agronomic Advisory Commission.

Finally, I wish to thank those members who have produced the papers, because those of us who have been responsible for organising this meeting realise that it does mean a tremendous lot of work and effort and it is much appreciated.

Now I should just like to say a word about procedure before we start. At this reunion we are going to try an experiment and we have arranged for two people to introduce each subject, one being an agronomist and the other being a technician. The papers will not be read, but we hope that the writers of the papers will be the first speakers after the two introducers. Then each group of papers will be open for general discussion. I would ask, if possible, for speakers to break up their remarks into short groups of sentences so that they can be translated as we go along, rather than have a long speech and then try and give a summary which may miss out some of the more essential points.

We realise that one of the main values of a Conference of this kind is to get out the reports as quickly as possible after the meeting has finished. With that object in view, we have appointed four reporters who have volunteered to prepare a summary of the discussion on each of the four groups of papers: they will endeavour to check up their reports with the speakers before we break up on Thursday. I will not read the names of the four reporters: section 1, Mr. Haasjes of Holland; section 2, Mr. Clark from African Explosives; section 3, Mr. Larsen of Fisons; and section 4, Mr. Carpentier of I.S.M.A. If speakers will co-operate with those reporters it will enable us to get our summarised report out within a matter of a few weeks.

I am taking the Chair for the first set of papers; Mr. Stevinius-Nielsen will preside this afternoon, Mr. Dior on Wednesday for the third set of papers and Mr. Charliers for the fourth set.

Gentlemen, we now come to the first section of our Conference, "The Influence of Radio-active Isotopes on Fertiliser Technology." There are six papers, and there is a slight alteration to the programme: the opening speaker from the technical side will be Mr. Horton and not Mr. Sherwin.

Mr. A. I. COLEMAN (United Kingdom): Mr. Chairman, may I be permitted to raise a matter arising from your address? You have not adopted our traditional formula of asking us to be brief, but the need, nevertheless, remains. I have calculated that if each member of the Conference were to give one spoken comment about each paper, he would have to restrain himself to fifteen seconds. The programme on that basis is indeed a congested one, and I wonder whether the arrangements that we have enable us to do full justice to the various interests involved. The authors are good enough to be here; the companies are good enough to permit us to have the information which is gained from months, and sometimes years, of investigation; the Committee has the onus of deciding what arrangements are best for an international conference. You have referred to the difficulties yourself, Sir, and they are very great for a conference embracing such a wide section of the sciences.

Last but not least, I wonder whether the arrangements enable us to do justice to ourselves. This congested programme, I suggest, is one which does not enable us to benefit to the fullest possible extent. I look into the future and I see that we shall soon have to bring each his own pet brain machine and communicate with each other electronically but then there are customs' formalities to think about.

I would ask, in view of the many difficulties that do exist on these occasions, that Conference procedure may be given an opportunity for discussion at conference level.

The CHAIRMAN: In answer to Mr. Coleman I would assure him that the difficulties which he has mentioned have been borne in mind by the Organising Committee and that is one of the reasons why we are suggesting that the papers themselves should not be read, but that we should confine ourselves to having an opener from each side and then a discussion. I am quite sure we do agree with you, that we do ask speakers to speak briefly and to the particular point which they wish to raise.

I now call on Mr. Horton to speak on the first section. Mr. Horton is speaking as a technician from the United Kingdom.

Mr. C. E. HORTON (United Kingdom): Mr. Chairman, delegates, I propose to divide my remarks into two parts: the first will be some general observations on the subject matter of our meeting; and the second will be one or two questions to the authors of the papers with which I hope they will be able to deal in due course.

We have set down before us as the object of this meeting, as you know, to discuss "The Influence of Radio-active Isotopes on Fertiliser Technology." We are given three headings: firstly, "Control of Production"; secondly, "Analysis"; and, thirdly, "Utilisation".

We are much indebted to the authors of the very able papers before us. In relation to the Agenda, you will notice that we have one paper which falls under the heading of "Control of Production," we have several papers which are concerned with the utilisation of fertilisers, but I do not think we are so far in possession of any new information on the use of radio-active isotopes for the purposes of analysis.

The problems that face the technologist and the agronomist in our subject are very old, and they have been tackled by the traditional procedures of chemistry, physics and biology. There is a vast literature dealing with the attempts to understand the translocation of ions and the very complex colloidal system which

exists between the plant, the roots, and the salts and soil system. Since the war we have been presented with a new tool: a fresh tool or technique is always of great significance in any science; evolution proceeds by steps and the introduction or discovery of a new technique is the starting point of a whole flood of fresh information and new ideas. This is true of our own subject and the availability of what we call labelled elements. These elements now have, or can be given, a characteristic such as radio-activity or particular mass which enables us to follow them and track them through their life history. This naturally has opened up entirely new fields of experiment and thought.

Many elements with which we are concerned are now available in a radio-active form. One of them is of particular interest to us - phosphorus - and it is fortunate that a radio-active form, P^{32} , is available for it has useful and easily controlled and manipulated characteristics from an experimental point of view. P^{32} has a half-life of 14.3 days so that it is possible to conduct experiments without being too depressed by the time factor, and at the other end there is no insuperable problem of disposing of the dangerous product because its life is too long and too intense.

It is, however, classed as one of the dangerous isotopes from a health point of view and, therefore, considerable elaborations of technique are necessary in handling it safely.

The element, P^{32} , can be purchased in America and in England and in other places. It is obtainable in the form of any commonly used phosphorus compound. It can then be incorporated, mixed, with the normal inactive fertiliser, and it is obvious that there is a problem of dilution and of mixture. You must have a dilution which is sufficient to take care of the level of radiation so that it is not excessive from the point of view of injury to plants and, at the same time, you must get a perfectly even distribution of the active radio isotope throughout the entire mass.

During the last ten years a very large number of experiments in America and in Europe have been carried out, with the result that we now know a great deal about the precautions which are essential to get sound results from the use of P^{32} . It is obvious that you must ensure that the radiation from the active material shall not be sufficient to disturb the biological life that you are examining; otherwise your result will be vitiated.

It is obvious too that you must establish that the product incorporating the radio-active material behaves biologically exactly the same as the inert material.

It is also very desirable, we have found from experiments, to do your experiments at more than one level of intensity of P^{32} ; preferably, firstly with no P^{32} , secondly with a certain level, and thirdly with a higher level. From three points of that sort on a curve you can draw more valid conclusions than from two.

Although great work has been done, it is the common belief that the subject is in its infancy, that there is room for improvement of techniques and for wider application in the study of nearly all the fundamental questions which biologists and agronomists have been asking, the process by which ions get transferred from solution, through the plant roots into the plant leaves. We are at the beginning of this subject, and it is the belief of us technicians that it is a fruitful subject and that most large research organisations will find it profitable to have facilities for handling radio-active isotopes in their experimental work. These may not only be phosphorus, but many of the minor elements, and when we come to nitrogen we may have to equip ourselves to use not the radio-active facility, but the mass spectrograph effect which can be handled and used when we have available nitrogen 15.

In view of the shortness of the time, I think it would be best if I deferred my specific questions on the papers to a later stage, particularly in view of the fact that delegates may wish to raise similar points to those I have in mind and may themselves do so.

The CHAIRMAN: I now call upon Mr. Haasjes from Holland, who is the opening SPEAKER from the point of view of the agronomist.

Mr. K. H. S. HAASJES (Holland): When discussing the influence of the use of radio-active isotopes upon the technology of fertilisers we are dealing with a topic which covers only a small part of the wide field of possibilities for the application of isotopes in modern research. It can be said that the use of isotopes and especially of radio-active isotopes has made some revolutionary progress during the last ten years; just as the use of various types of plastics has progressed for all sorts of purposes in modern society. It is hardly possible to mention a method of application of these materials which has not yet been explored, or which is not being explored at the moment. We all know from our own experience in the factory and the laboratory that these plastics have enabled the man in the factory or in the laboratory to solve many technical problems and to improve existing systems which did not work as perfectly as was desired.

Similar considerations apply in connection with the uses of isotopes. It is not my task to assess in this introduction the value of isotopes in the technical field, such as improvement of production methods, development of new products, checking of the production process, chemical analysis methods, etc. I have to confine myself to a few remarks on the usefulness of radio-active isotopes in agricultural research, which is part of the immense field of biological and physiological research. Being mainly interested in the influence of fertiliser application on plant growth and crop production, my remarks today will be kept within the more narrow limits of problems and research regarding the effectiveness of fertilisers.

Most of the papers to be discussed will deal with the use of radio-active phosphorus in research on fertilisers. This is not due to the fact that we are meeting each other here as superphosphate manufacturers or research workers connected with the industry having only a limited interest in fertilisers other than those we manufacture ourselves. It might be that the technical man is supposed to have an all-round knowledge on items concerning his own plant and in addition on those of corresponding plants with similar production processes. The agronomist, however, would be useless if he only knew everything about his own products. The problem of fertility and fertilisation is so complicated and tied up to such an extent with other problems of crop production that his knowledge has to cover large parts of the entire field of agricultural science.

It is in this light that the subject which will be discussed during this Joint Technical-Agronomic meeting must be seen. The agronomist has to deal with subjects beyond the scope of phosphates only. Nevertheless, the research on phosphates in fertiliser, soil and plant will be emphasised here. As I have already said, this will not be done because the agronomist confines himself to phosphates only. The reason can be found in the subject itself. It will be seen that most of the research has been carried out with the aid of radio-active phosphorus. Evidence of this can be found in the international literature on the use of radio-active isotopes for agricultural research purposes. The fact is that radio-active phosphorus was one of the first isotopes which was widely available in adequate quantities. Moreover, its physical properties are rather suitable and consequently it has been used on a large scale. All this has led to the result that P^{32} has played an important part in agricultural research, all the more so since phosphate is one of the main plant nutrients and the behaviour of phosphate in soil and plant has for a long time been a mystery in many respects. Thanks to the fact that radio-active phosphorus became available some of these mysteries have been solved and the solution of others is well on its way.

It is the intention of the speakers to give you today a few examples of what could be attained through the use of radio-active isotopes. It will be clear that on the one hand P³² enables the agronomist to arrive at the solution of a problem much quicker than with the existing conventional methods, and on the other hand to solve problems which could not possibly be solved at all with the older methods. In this latter respect, one of the most striking examples is the determination of the percentages of the total P-content in a plant, which come from the phosphorous already present in the native soil and from the fertiliser applied to the soil. Furthermore, it is now possible to determine what source of phosphate the plant prefers in its various growing stages, even when mixtures of phosphatic fertilisers of different availability are applied. These points and many other very interesting subjects will be dealt with, such as methods of application to the soil and to the leaves, P-fixation, determination of available soil P, uptake of P, effectiveness of P fertilisers related to size of particles, etc.

Most of the experiments which we are going to discuss have one thing in common, namely, that the research worker had to work out his own methods and to find his own ways to wrest the secrets from mother nature, because he was setting his foot upon new paths by using new methods.

Thanks to their persistency, results have been obtained which will enable our industry to improve the effectiveness of our products and which will supply our commercial departments with data to be used either to inform the customer about the use of these products or for advertising purposes.

We have these objects in view when carrying out experiments, but cannot prevent results being less favourable than we would like.

It is with such pleasure that my colleagues are going to speak of their experiments and those of other workers on the use of radio-active isotopes in fertiliser research. We hope that the discussions will be enlightening and will yield some aspects which may be useful for future work.

THE CHAIRMAN: Thank you very much, Mr. Haasjes.

I am now going to throw this open for general discussion. I would suggest that if possible speakers frame their remarks in the form of questions on the actual papers which we have got before us, and they can then be answered by the writers of the papers. If we do it that way, we shall get down more to actual details and avoid general, rather wide discussion on this very complex matter.

PAPER NO.760 - "RADIO ISOTOPES AS A TOOL IN STUDYING MIXING METHODS"
by I.A. BROWNLIE (United Kingdom)

Mr. A.I. COLEMAN (United Kingdom): May I comment on Mr. Brownlie's paper? I found it to be extremely interesting. It does set out in an extremely simple way the organisation and procedures which are necessary to enable investigations of this kind to be commenced. I think it gives us great reassurance because some of us may have felt a little worried about these radio isotopes, what they would do to us if we were not looking. Mr. Brownlie, in effect, says one should take the right precautions and there is no risk.

I should like to ask a specific question about the part of Mr. Brownlie's experiment which is concerned with the tagging operation. At this stage he says that he has dissolved the radio-active sodium carbonate in solution and sprayed it on to a minor additive in a paddle mixer. It seems to me that such an operation of itself need

not be perfect as a mixture. Therefore, in the tabulations on the penultimate page, Table I, the variations of counts reported may reflect in part the variations of imperfect mixings in the tagging operation.

MR. I.A. BROWNLIE (United Kingdom): Mr. Chairman, in answer to that question, I should like to say that in the paper I have not specifically mentioned the application of the radio isotope in the concentrated stage. We are fairly satisfied that the methods we used were sufficiently good by doing a smaller experiment on a smaller scale with a more dilute activity, first of all spraying the radio isotope on to the material in the small mixer, and then doing a similar type of analysis on that and being able to deduce from that, that the first stage was, in fact, good enough to allow us to go on to the second one.

MR. W. CHARLIERS (Belgium)(Interpretation): After reading Mr. Brownlie's paper, I believe that the proposed method of using radio-isotopes for studying mixing is perfectly shown in the problem which is daily becoming more important - the introduction of trace elements into macro elements. I should like to ask the author of the paper if the sodium carbonate used in his experiments can serve as a general example of introducing trace elements.

In other words, can it be said that a mixture which seems perfect by this method should be equally suitable when we introduce the trace-elements which are widely used in practice, such as copper, zinc, nickel, iron, cobalt etc. and among these elements, is it possible to use any of them as easily as the tracer Na^{24} used by the author. I repeat my question: I should like to know if this method can be extended to trace-elements such as those which are often used in practice - copper, iron, zinc, nickel, cobalt, etc., and are radio-isotopes of these elements available, and which of them can be used?

MR. I.A. BROWNLIE (United Kingdom): I would say that there is no case for using radio isotopes when you have elements which can be easily chemically analysed. We have in this particular example in the paper quoted radio isotopes for mixing such things as antibiotics and vitamins in very small amounts, because the number of tests which we had to do and the difficulty of analysis would have made the length of time required for the investigation very long and uneconomically attractive so that for each particular case I think you have got to sum up the position and make sure whether it is advantageous, whether it is wise, on economic grounds and on health grounds, to go ahead with radio isotopes in place of the established chemical methods.

MR. F. FLEURY (France)(Interpretation): I should like to ask Mr. Brownlie a question. How small a scale can be used for this process still to be useful? Mr. Brownlie in his experiments mentions a sample of 1 lb. out of 100 kgs., and the impulses are counted in this sample. Would the process be just as valid for very small quantities, and could we find out, for example, whether each granule in a granulated fertiliser contains the same quantity of trace-elements, as Mr. Charliers said?

MR. I.A. BROWNLIE (United Kingdom): The sample size has to be determined for each particular investigation. In the case we have quoted it was a sample of 1 pound i.e. 453 grams. The size of the sample determines the activity which you must use in the investigation and there is no reason, as far as I can see, why you could not go down at least to a number of granules, perhaps not 1, but say 10 or 20. It may be that when you have calculated the amount of activity to be used, it would be rather dangerous for the people doing the job, so that the only difficulty with the size of sample, I think, is in the medical hazard of using the radio isotope.

MR. P. CRAVEN (United Kingdom): I have two questions with reference to Mr. Brownlie's paper. The first one deals with Table II. I am not quite clear how it is that one can assume that method A is not as good as method B, when the 5-pound sample gives a probability of 99.9% and there is, therefore, only a difference of 0.1% which would not appear to be significant at that stage, although in the case of the 1-pound sample there is a definite difference. Whether or not that is due to the sample size or the mixing method does not appear clear to me. Referring to Table I, in mixing method A, assuming that is not so good, one does get this general pattern of an increase in counting, in this case from approximately 800 up to 1000 for sample C, dropping off slightly, up to 1000, and then dropping down again. In other words, do not these counts rather infer that a certain amount of segregation is occurring? That is question one.

Question two is whether or not Mr. Brownlie could give any suggestions on how this technique could be applied to granulation plants where we have much larger tonnages involved. It would not appear to be satisfactory to spray a large tonnage due to the fact that in drying it off, possibly re-preparing it, one is going to get a difference in size distribution which will of itself lead to further segregation?

MR. I.A. BROWNLIE (United Kingdom): On the first question regarding Table II and Table I, the reason for method A approaching method B in the last column is that you are doing two things: you are taking, first of all, a larger sample in the case of the 5-pound sample, and you are taking a wider probability limit of 90 to 110. Therefore your results have come in close together at that point. You would not be able to say, if you had adopted those conditions, that method A was appreciably worse than method B. The time when it does become poor is when you go to the more rigid limits of a 1-pound sample and 95 to 105 per cent limits. The results in Table I were put in just as a general example. I do not want you to place too much significance on whether there was segregation or not. It is possible that you can do that type of thing from these results, and discover whether you are getting segregation, but it is put in here merely as an example of the type of results that you can get; for example, the sort of range of activities you get, range of counts per sample due to the nature of radio-active counting. There are, I may say at this point, statistical methods of determining whether any particular result is out by quite a lot due not to the mixing or to the material you are using, but due to a random fault occurring in your counting system.

With regard to the other question, the application to granulation, we have not specifically mentioned in the paper particular applications to fertilisers, but there are various things which one might do. I do not think there is any particular reason why you should not apply this method to granulation. It may be that you would find chemical methods more attractive for a specific problem; in granulation you are normally dealing with macro constituents in the mix, but you may have occasion to use trace elements or, for example, antibiotics in the fertiliser granules. I suggest it might become more attractive to use it in that case.

There is one other possibility, that you might get away from the mixing aspect and study such things as the growth of small granules in granulation procedure. It is a little bit difficult to see just how the granules are building up; for example, there may be the feeling that small granules of a certain size - what you might call pin-heads - do not tend to grow very rapidly in the granulation and circulate in the system, and you might think it worth

while to apply this technique to studying a particular granule size.

M. SOUBIERS (France) (Interpretation): I should like to ask a more general question. In the fertiliser industry, what is the limit in the use of radio-isotopes? One generally hopes, by the use of radio-isotopes - at least according to certain accounts - to be able to identify and to determine in the phosphorus which the plant absorbs, the part which comes from the fertiliser and that coming from the soil. Thus one deals with questions of localisation and of utilisation of fertilisers over one or several years. But here there is a question of distinguishing between the phosphoric acid from the fertiliser and that from the soil. If the fertiliser remains well isolated in the soil, and if the phosphorus - or at least the radio-activity in the phosphorus - in the fertiliser does not mix with the phosphorus in the soil, then it is possible to distinguish between the amount which comes from the fertiliser and the amount which comes from the soil. In this case, the technique is correct. But if there is an isotopic exchange between the phosphorus in the fertiliser and that in the soil, then we are wrong to measure the final radio-activity. In this case, we can only use the radio-isotope method to measure the total quantity of exchangeable phosphoric acid in the soil. This would be all right.

I put this question to the technicians and agronomists present. What is their position when faced with this general problem?

MR. S. LARSEN (United Kingdom): The question of exchange between the applied labelled phosphate, and the soil phosphate is a very big question, and we have not solved it yet. But there must be an exchange; we cannot avoid it. Therefore if we are going to do experiments with labelled phosphate, it is better to have a complete exchange than to have a part exchange. For example, in an experiment where we mix the phosphate throughout the soil, in order to get an even distribution, we shall have the best facilities for a complete exchange. But if we are doing field experiments for example to compare placing the phosphate in rows with broadcast application, we shall in the first case, have little opportunity for exchange; in the second case the opportunity will be better and that will have some bearing on the results obtained.

I would also add that the exchange process takes time, and it will be three weeks - maybe several weeks - before we have an equilibrium. We need to reach a certain state of equilibrium before we can draw any conclusion from the experiment. I think that answers the question.

MR. SOUBIERS (France) (Interpretation): You did not completely answer the question. I should like to know the limits of utilisation of P₃₂ in the research on fertilisers. You said that you can have a complete exchange, but that means that you can determine the total quantity of P₃₂ which existed in the soil plus the quantity brought by the fertiliser. But you cannot identify the P₃₂ from the fertiliser.

MR. S. LARSEN (United Kingdom): I should like to know the limitation myself that is why we are going to do some experiments on the problem. But what I am concerned with is the isotope dilution in the soil. I think distinguishing between the different sources of phosphorus in the soil is rather difficult. If I could express myself in my way of thinking, I would speak about an available pool of phosphorus in the soil. By adding soluble phosphate to the soil, this soluble phosphate will react with the soil and exchange with a certain part of the soil phosphorus. This reaction will be expressed in the isotopic dilution or, strictly speaking, in the

specific concentration of P32 in relation to P31. That is the only answer we can get. We cannot say for certain that we are taking up a certain amount of our phosphorus coming from the fertiliser and a certain amount coming from the soil: what we can say is that the plant is taking up a mixture of the two types of phosphorus, and the ratio of this mixture is expressed in the specific activity of the phosphorus in the plant or in the soil extraction.

THE CHAIRMAN: Gentlemen, I told you when we started that this was in some ways an experiment. What I would suggest, if I may, subject to your approval, is that we invite questions on the various papers so as to more or less control the discussion. I will now ask if there are any more questions on paper LE/760 presented by Mr. Brownlie?

MR. K. POLLE (Holland): Mr. Chairman, Mr. Brownlie has written on page 4 of his report:

"We have tried to show that radio-isotopes constitute an efficient tool which may well be applied more widely in the fertiliser and allied industries."

May I ask whether Mr. Brownlie has any idea about the costs and the ease of handling in practice of the fertilisers?

MR. J.A. BROWNLIE (United Kingdom): I can probably best speak for the costs in the United Kingdom and assume that they will apply pretty generally all over. The cost of the radio isotope itself is not large. For a particular series of experiments you can get, say one gram of sodium 24, as sodium carbonate, from Atomic Energy, Harwell, for, I think, about £3. per unit. That, in the particular experiments we were doing, could be applied to several tons of material and last for, perhaps, one set of experiments. So the actual cost of the isotope is not high. The initial cost of apparatus for doing experiments is, in our case, about £150. That, of course, can be spread over the whole system of experimental work.

As far as other costs are concerned, they would be similar to normal investigations.

There is just one other factor: we dealt with the cost side of it, but on the saving side of it there may be quite a substantial saving in the time which would have been taken normally in chemical work. I mean, the particular section that we have concerned ourselves with, would have taken us perhaps five or six times as long to do the chemical analysis. So there is a saving as well.

MR. K.A. SHERWIN (United Kingdom): The point I should like to have made was not a question on the paper, but on the application of remarks made in connection with granulation.

We have had a little experience in using radio-isotopes for studying the behaviour of production plants, making granular fertilisers. I should like to say that there are distinct limitations to the answers you may get easily. If you are interested in some aspect of the time of throughput of certain parts of the plant, you can get a fairly satisfying peak-type curve showing the time at which a fertiliser mixed with the tracer which you added at some earlier stage. You can get this hump at other parts of the plant and thereby deduce the rate of passage between the two points. If you wish to apply this technique to granules of particular sizes, then I think you would have to separate samples of material into fractions according to certain definite size ranges, and establish the amount of active element in them. Then I think you could perhaps determine

differential rates of passage for the different sizes of material. You then come to a question of statistics when you wish to interpret the accuracy of the answer. I would also add that if you use a considerable quantity of tracer, you get a general level of activity in the plant, in the building and in the storeroom which has to be taken into account.

MR. I. A. BROWNLIE (United Kingdom): On the subject of using radio-isotopes in granulation plants, I think the main point of this paper has been to illustrate the possibility of using isotopes on a large scale. I believe there has been, until the present time, a natural reluctance to use them because of the question of the danger. We have tried to show that these dangers can, in fact, be controlled.

Mr. Sherwin has mentioned the fact that using it in a granulation plant would involve the difficulty of spreading isotope material throughout a factory in dangerous amounts. We have been, in fact, very conscious of that difficulty, and in our own experiments we have been able to control it in such a way that the tests on masks used on people working there have been almost nil.

Therefore, may I just summarise by saying that if the paper has achieved the object of encouraging people to think in terms of using radio-isotopes for their particular problems, then it will have achieved something. They may find, after they have assessed all the difficulties of the procedure that it is not, in fact, worth while, but I think if we get thoughts moving along the lines of new techniques we shall have accomplished something worth while.

MR. A. T. BROOK (United Kingdom): Mr. Brownlie, in answer to a previous question, said he thought his process could be applied to finding the growth of granules in the granulation plant. I should like to ask Mr. Brownlie if, when using activated sodium carbonate solution, he would expect to find different radio-activity in granules of different sizes made in the process? If there were no difference in radio-activity, how would he propose to study the growth of the granule size itself?

MR. I. A. BROWNLIE (United Kingdom): In answer to Mr. Brook, although we have not actually applied this technique, I think the way to do it would be, at the beginning, when you have the recycle of small material in the granulation plant, to apply the radio-isotope to that particular size, and then, instead of considering the activity associated with various sizes of granules, to determine the time required for the activity in the plant, to go down to a pretty small value; in that way you would have some idea of whether the small material was, in fact, being built upon by fresh material coming on or whether it was merely going round and round the plant.

PAPER NO. 150. - "AGRICULTURAL APPLICATIONS OF RADIO-ACTIVE PHOSPHORUS" by K. KAINDL (Austria)

Mr. N. CHARLIERS (Belgium) (Interpretation): I should like to ask whether there is correlation between the curves of absorption or desorption of elements by the plant and the yield, because for an agronomist the main point is to find the influence of the use of a fertiliser on the yield of a crop. Taking as a basis the penetration, the up-take of the nutritive elements in the plant, you may perhaps find out the yield which would correspond to that up-take. It would make great progress for the agricultural research.

In other words, is there anybody who is doing research on up-take of plant nutrients either with chemical methods or those using radio-isotopes who can say whether there is a correlation between the curve of up-take or of desorption of plant nutrients and the yields they obtain?

PROF. A. FRUHSTORFER (Germany): There is not always a relation because the up-take depends on the time of application. If you use a fertiliser very late in the spring or in the summer - for instance, at the end of June for potatoes - then you get a very high up-take of phosphoric acid, but it is not reflected in the yield. But I must say that is an exception. As a rule the up-take of nutrients and the yield go in the same direction, but there are exceptions.

MR. S. LARSEN (United Kingdom): There must always be some correlation between absorption of nutrients and growth of the crop, otherwise why use fertiliser at all. The increase in up-take of nutrients is almost a straight line up to a certain level. The yield does not increase proportionately beyond a certain point on the up-take curve and this means that you can have an increase in up-take without a corresponding increase in yield. This is what is called luxury consumption.

MR. N. CHARLIERS (Belgium)(Interpretation): Do the research workers always think of the correlation between the up-take of plant nutrients and the yield? Most people think there is a correlation between the up-take and the yield. This is not always the case. There can be a specific deficiency of one element in the soil simply because another element has been added. There might be a deficiency which could give rise to the consumption of another element; for example, the relation between magnesium and phosphorus.

MR. SOUBIES (France)(Interpretation): From the theoretical point of view, the question raised by Mr. Charliers is of course, very clear, but there is not always a correlation between the nitrogen up-take and the yield from the practical point of view; there is happily a perfect correlation between the phosphorus up-take and the yield, which means that you can apply phosphoric fertilisers in advance and without wastage.

MR. F.R. SCHOFIELD (United Kingdom): Speaking as a technician, may I ask whether it has been shown without doubt that the plant is not selective in any way in its performance to the radio-active material, and the non radio-active phosphorus? Also, has the radio-active potassium, which may also be present, any effect on the up-take of the radio-active phosphorus?

MR. N. CHARLIERS (Belgium)(Interpretation): In his paper Mr. Larsen answered the question you raised. There is no selective absorption of active phosphoric acid or of inert phosphoric acid. The essential thing is not to have too high a concentration of labelled phosphoric acid in the soil in order to avoid radiation damage which could falsify the results. That is why Mr. Larsen recommends applying labelled phosphoric acid to the soil and not to the fertiliser.

MR. C.E. HORTON (United Kingdom): I should like to refer to page 7, figure 4. It is figure 4(b) at the lower part of the page which puzzles me. It looks from the diagram that the up-take of the fertiliser at the first harvest is very small, and I wondered whether any explanation could be given for that rather puzzling result. I would particularly ask whether it is possible that it could be due to this undesirable concentration of radio-activity that can sometimes happen and vitiate experiments of this type.

MR. LARSEN (United Kingdom): In the absence of Mr. Kaindl, I would say that this could be due to the localisation of the fertiliser, as the intensity of radio-activity might be too high at the beginning in the zone where the fertiliser was localized to allow the plants to absorb the fertiliser. As time passes, so the radio-activity of the fertiliser diminishes, because the radio-active element decays and at this point, the plant can then take up the fertiliser.

PAPER NO. 149 - "THE APPLICATION OF RADIO-ISOTOPES IN THE STUDY OF SOIL FERTILITY" by S. LARSEN (United Kingdom)

DR. B. RAISTRICK (United Kingdom): I should like to ask Mr. Larsen three questions. Firstly, towards the end of his paper he suggests the possibility of putting radio-active phosphorus into the soil, effecting an exchange there and then comparing the up-take from a non-radio-active applied fertiliser with the radio-active phosphorus taken up from the soil. I should like to ask him if the treatment of the soil to make it radio-active in this way affects the phosphorus state of the soil and, therefore, are the results useful?

MR. S. LARSEN (United Kingdom): The relevant question is whether the application of P^{32} plus a certain amount of P^{31} will influence the phosphate status of the soil. As we all know, it is possible to have P^{32} practically as a pure element; that means without any P^{31} . That is what we call 'carrier-free P^{32} '. But that solution or salt - it could be a salt - is very difficult to handle. Therefore, we are forced to add some carrier as a certain amount of P^{31} . This can be done in such a way that the added amount of phosphorus will be negligible compared to the amount of phosphorus already present in the soil. Therefore, my answer would be that there will be no significant alteration of the phosphate status of the soil by using nearly carrier-free P^{32} .

DR. B. RAISTRICK (United Kingdom): My second question, Mr. Chairman, concerns the section of the paper in which Mr. Larsen discusses the case where rock phosphate is irradiated in a pilot to convert some of the P^{31} to P^{32} . He then goes on to say that, in his opinion, the failure of crops to take up any at all of this P^{32} is due to the concentrated radio-activity in some of the fine particles.

A lot of papers have been published on this subject, and his opinion is at variance with the opinions of other people: I certainly do not subscribe to it myself. But I suggest that Mr. Larsen has the means in his own hands to solve the problem because, if the failure to take up phosphorus is due to the radio-activity, all he has to do is to repeat the experiment next year when according to my calculation, the radio-activity will be reduced by 100,000,000 approximately. That is true, of course, if P^{32} is the main trouble. If it is calcium 45, that problem can be solved just as easily by doing a comparable experiment with, say, irradiated sodium phosphate and putting P^{32} in there, so that the calcium does not affect the issue. Therefore, it is fairly easy to solve the problem. That is my suggestion. I should like to know on what evidence Mr. Larsen bases his opinion, that the failure to take up any phosphorus at all is due to the radio-activity in the rock.

MR. S. LARSEN (United Kingdom): The evidence is to be seen in Table 1 in my paper where I compare three calcium phosphates, monocalcium phosphate, dicalcium phosphate and hydroxyapatite. In the experiment I used two levels of P^{32} , 0.01 and 0.1. Looking at the experiment with hydroxyapatite, you will notice there is some very marked difference between the utilisation of what you would call the 'hot' phosphate containing 0.1 millicuries P^{32} per gram P^{31} , and that containing only 0.01 millicuries. That is my evidence. But I must say that the field experiment with rock phosphate labelled by this particular technique was a shot in the dark; it is a rather old experiment and I saw no reason to repeat it.

DR. B. RAISTRICK (United Kingdom): Mr. Chairman, before I ask my final question, I should like to say that I think Mr. Larsen's evidence in Table 1, could be used to support the alternative view, that the phosphorus is being carried to a lower state of oxidation. The evidence could be held to support the alternative view just as easily as he thinks it supports his view.

Mr. S. LARSEN (United Kingdom): Dr. Raistrick spoke about oxidation. Was a lower phosphate compound produced in the pile? Was that your question?

Dr. B. RAISTRICK (United Kingdom): I am thinking of the alternative view that the failure to take up phosphate from irradiated rock may be due to conversion of the ortho phosphate in fluorapatite to a form such as hypophosphate.

Mr. S. LARSEN (United Kingdom): I discussed this point with gentlemen from the Danish Fertiliser Company, Mr. Carlsen and Mr. Hornshøj-Møller. We got in touch with Harwell and they told us that if we heated the rock phosphate as received from the pile we would have a fair chance of converting it back into ortho phosphate. That may be true or may not be true; it is not really proved. I knew the problem very well, but it does not apply in this experiment because the phosphate was actually synthesised from dicalcium phosphate, and the dicalcium phosphate was produced from ortho-phosphoric acid. In order to be safe, the irradiated phosphoric acid coming from Harwell which was supposed to be 100 per cent ortho phosphoric acid was digested with concentrated nitric acid. In that case, I can say I am quite sure that it was ortho phosphate.

Dr. K.C. SCHEEL (Germany): I have made several experiments with hydroxyapatite and with other substances, and I found that the application of activated phosphates had no disadvantages in connection with crops. We have gone so far as to apply 0.5 millicuries per gram of substance, and have also gone so far in other experiments as to apply 2 millicuries per gram of P_2O_5 without finding any deleterious results as far as the crops were concerned. I would refer to the apparent great difference, and to the very small application of 0.01 millicuries per gram of substance. I wonder whether this difference is due to an error in measurements, as such a small quantity of radio-active material was applied. In our own experiments we have found that the action of hydroxyapatite on the crops was a very small one indeed, which fact I think also agrees with the results found by Mr. Larsen.

Mr. S. LARSEN (United Kingdom): I cannot produce the evidence here, but I have got it elsewhere and there is no question about it. I would like to stress that only under certain conditions can you measure the influence of P^{32} in hydroxyapatite on the up-take of phosphorus from that source. This point is discussed in several papers; and I would only mention the work of Dr. Scott Russell of Oxford.

Dr. B. RAISTRICK (United Kingdom): Mr. Chairman, I should like to ask Mr. Larsen what form of dicalcium phosphate he uses in the experiments. Dicalcium phosphate is a very important chemical in fertiliser practice now. The coming of nitro-phosphates over the past few years and ammoniation, of course, converts superphosphate into dicalcium phosphate. A great deal of work has been done by people who just describe the product as "dicalcium phosphate". The anhydrous compound exists as well as the dihydrate. People call anything "dicalcium phosphate" which has a phosphorus calcium ratio of 1 : 1. The state of hydration is pretty important. An analogous system to dicalcium phosphate is calcium sulphate, of course. Anybody who has tried to make Plaster of Paris with either the anhydrous compound or with the dihydrate will know it is impossible, whereas the hemi-hydrate gives you a good plaster. That is analogous in my opinion.

I do urge anybody who works with dicalcium phosphate to do two things: to say what kind of dicalcium phosphate, and to give some idea of the purity of the material that they use. A great deal of work has already become useless because different forms have been used and we cannot afford to spend years and years of research and

manpower with people working with either undefined or impure materials.

Mr. S. LARSEN (United Kingdom): I can give you the formula for dicalcium phosphate - it is $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$. We worked out a method of preparing this form of dicalcium phosphate years ago. I have given a full description of the method elsewhere, but I apologise for not having mentioned it here. I am in full agreement with you: we have to know what we are going to work with. It may be monocalcium or dicalcium phosphate or hydroxyapatite.

THE CHAIRMAN: We will take paper PA/151 by Dr. Scheel now. Are there any questions anyone wishes to raise on this paper?

PAPER No. PA/151 - QUANTITATIVE DETERMINATION BY MEANS OF P^{32} OF THE ABSORPTION OF P_2O_5 BY LIVING PLANTS -
by K.C. SCHEEL (Germany)

THE CHAIRMAN: No questions? In that case, we will proceed to Dr. Frühstorfer's paper PA/152. Are there any questions on that paper?

PAPER No. PA/152 - DETERMINATION OF THE P_2O_5 UP-TAKE FROM POWDERED AND GRANULATED SUPERPHOSPHATE BY MEANS OF P^{32} -
by A. FRUHESTORFER (Germany)

Prof. A. FRUHESTORFER (Germany): There is an Appendix to my paper. Maybe you missed the link between the application of powdered superphosphate and the application of granulated superphosphate placed in a layer. The link is the application of granulated phosphate broadcast and distributed into the soil.

Mr. Chairman, you will find an experiment with these three forms of application. In our research station the application is the main task and for many years we have been working on the influence of application. Before we used isotopic P_2O_5 , we found that the distribution, the broadcasting of P_2O_5 in a phosphate which is soluble in water is not good for the up-take because we promote fixation. We have found that the up-take by means of activated superphosphate goes in the same way. We found that the up-take of powdered and broadcast superphosphate is inferior to the application of the granulated form, and this application is inferior to the application in layer; but we found that the time of the efficiency varied. The powder superphosphate has the best efficiency at first. After two weeks the efficiency of the granulated far surpasses the powdered form, and after four weeks, the placement in the layer is the best.

In this study we did not take into account the exchange. You saw that in the up-take the exchange of a granule is not so good as the exchange of powdered phosphate which is well distributed into the soil. But it is my opinion that we are not interested in exchange; I think we are interested in avoiding exchange and in avoiding fixation. This is the reason why we make use of granules because they cannot react with the soil so quickly as powder superphosphate.

The CHAIRMAN: Although, in some ways, this is linked up with the discussion this afternoon, I think if there are any questions, relating mainly to the radio-active isotope aspect, we might deal with them now.

M. L. DIDIER (North Africa)(Interpretation): What is the pH of the soil you used?

Prof. A. FRUHESTORFER (Germany): The pH of the soil is about 5.

M. L. DIDIER (North Africa)(Interpretation): I think the soil which was used was very acid and, therefore, the conclusion arrived at was to be expected.

Prof. A. FRUHSTORFER (Germany): You see, in our country most of the soils have a pH between 5 and 6, and our arable soils in Northern Germany must have this pH value. If we have a higher value than 5.8 or 6, then we get a deficiency of manganese. Therefore in the region of Luneburg most of our soils have a middle value, pH value of 5 to 5.6.

Mr. K.A. SHERWIN (United Kingdom): May I ask the author whether there was any special reason for not applying powder fertilizer in bands?

Prof. A. FRUHSTORFER (Germany): You mean the application of powdered superphosphate in layers. We carried out a large experiment and the difficulty of working with isotopes is great. We have to make thousands of counts and we are not ready with these experiments. But I can answer your question. From our former experience when we worked without isotopes, we found our best results were when we used powdered superphosphate in layers. When we used granulated superphosphate in layers, the granulated superphosphate was better than powdered when broadcast and distributed in the soil.

M. SOUBIES (France)(Interpretation): I should like to ask the following question; it is said that granulated superphosphate is more efficacious than powdered superphosphate mixed with the soil; but in the paper I have before me, it seems to me that the powdered superphosphate is mixed with the soil, while the granulated superphosphate is applied in layers. Is this difference in yield caused by the different applications of fertilisers or by the granulated fertilisers as opposed to powdered fertilisers?

Prof. A. FRUHSTORFER (Germany): I have given you an appendix and the answer is in the appendix. We now have three rows: the second row is granulated and broadcast; the third is granulated and applied in layers.

Mr. C.E. HORTON (United Kingdom): Mr. Chairman, I should like to draw attention to an important statement at the bottom of page 1, paper PA/152. The last sentence there says:

"Water-soluble phosphates, therefore, are more at a disadvantage than at an advantage on acid soils and on soils with a pronounced power of fixation".

I wonder if the author could quote or describe any concrete field evidence for that statement.

Prof. A. FRUHSTORFER (Germany): I think it is known that acid soils have the ability to fix phosphoric acid. If you have a form of phosphate such as superphosphate which is chemically very active, this fixation goes very quickly. If you have an inactive one such as basic slag, the fixation is retarded. This is the reason why superphosphate in pot experiments is mostly inferior to basic slag.

Mr. D.E. SIMPSON (United Kingdom): It is necessary to distinguish between experiments in pots and in the field in this connection. When fertilizer is broadcast in the field it is not so intimately mixed with the soil as it is in pot experiments.

The CHAIRMAN: Gentlemen, if there are no more questions on these papers, we come to the final paper this morning which is a review prepared by Mr. Carpentier of papers presented last year at the Geneva Conference on the peaceful uses of atomic energy. I think you will all agree that it is a very comprehensive document. Are

there any questions anybody wishes to raise on Mr. Carpentier's paper?

PAPER No. PA/154.- REPORT ON INVESTIGATIONS ON THE USE OF RADIO-ACTIVE ISOTOPES IN AGRICULTURAL RESEARCH -
by L.J. CARPENTIER. (I.S.M.A.)

Mr. L.J. CARPENTIER (I.S.M.A.): All the papers mentioned in my review are available and members wishing to see them should apply to the Paris Office of I.S.M.A.

Mr. N. CHARLIERS (Belgium)(Interpretation): I should like to make a very small comment. You say, on page 3 of your summary,

"Further, research carried out with S^{35} on roots placed in water have enabled us to realise that the concentration of ions of the external part of the roots is the same as that in the surrounding medium".

Does this not seem to contradict what we have previously noted with regard to the luxury consumption of sulphates in the paper we prepared some time ago. We have a curve of comparative absorption of the ions which shows a luxury consumption and the same final exterior and interior concentrations, whilst in the special case of the SO_4 ion we do not find the same concentration. Your statement seems to be at variance with what has been found using another method.

Mr. L.J. CARPENTIER (I.S.M.A.): If I remember rightly, I think this statement referred to one of the papers where the author was investigating the ionic concentrations on the external root surface and in the surrounding medium. I think it is a question of momentary equilibrium.

The CHAIRMAN: Gentlemen, if there are no other questions on Mr. Carpentier's paper, I will close this session.

Before you leave, I should once again like to thank the authors of these papers, and I would ask them to convey to their companies our appreciation of the companies' allowing them to publish the papers and to come and speak to us at this gathering. I hope you will agree with me that we have had a very useful morning's work.

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JOINT TECHNICAL-AGRONOMIC CONFERENCE

LAUSANNE 24th-26th September 1956.

Report of Discussions

Afternoon Session 24th September 1956.

In the Chair: Mr. H. Stevanus-Nielsen.

THE CHAIRMAN: We will now start on Section 2. I think you are aware that this section is composed of three papers, and you will be aware that these three papers are divided into two sub-sections. The first paper is "Granular Compound Fertilisers". The third one is "Moisture Content and the hardness of Granules": this is also a technical paper which tells us of the hardness of granules. In the middle is the agricultural part, "Effect of Particle Size on the effectiveness of Fertilisers".

I think you are aware that Mr. Simpson's paper is closely connected with some of the problems we discussed this morning. I, therefore, propose that, if some of you would like to continue the discussion of papers 152 and 151 from this morning, we could take it in connection with paper 145 this afternoon.

I will now call upon Mr. Sherwin who is our first introducer.

MR. K.A. SHERWIN (United Kingdom): Mr. Chairman, Gentlemen, I assumed that the intention of the Committee was that the papers given under this section would have some inter-relation, and that on one side we would have technical papers from the agronomic people telling us exactly what size of granule they want; and on the other side we would have the story from the producers telling them what size they would get.

I looked at the three papers with this in mind and I would like, therefore, to mention Mr. Simpson's paper first because he is the one who should give the lead to the manufacturers. What I hope to show is that the size is very much in the hands of the manufacturers for a number of reasons which are shown up in the papers.

Mr. Simpson's paper quotes a summary of another paper by some Americans and also quotes a summary of some experimental work of I.C.I. If I may be permitted to summarise his own summary of all that, the result is, I think, that generally speaking where you have nitro-phosphate or dicalcium phosphate there is some evidence that the up-take of P_2O_5 is adversely affected by increasing the granule size.

On the other hand, where soluble phosphates are concerned, there is no generalisation possible except to say that granules are really unfavourable but, in specific cases, they are definitely better. I suggest speakers in the discussion might take me up on that, but that is how I read it from the point of view of the technicians who are responsible for making these things.

From the technical point of view, Mr. Brook's paper, I think, gives a very good indication of the difficulties of making this type of compound fertiliser within specific size ranges. But I suggest that the problem is broader than that and that we might have some comparison between other methods of making compound fertilisers or fertilisers of any kind in specific sizes.

I should like to illustrate this by referring first of all to the manufacture of superphosphate by the DORR process as being one extreme in the manufacture and, on the other hand, to Mr. Brook's own paper dealing with fertilisers commencing with solid materials, that is superphosphate, triple-superphosphate and other salts. The triple-superphosphate process starts with a slurry, resulting from the reaction of phosphoric acid and rock phosphate. The problem, as I see it, is to extend this slurry over a sufficient area to be able to dry it in some kind of apparatus and end up with a respectable looking product.

Now the DORR process is so arranged that it smears the slurry on to the surface of a large quantity of previously-manufactured material which has been broken down to as fine a condition as possible. In other words, the production of fine materials is at a premium in this process. One, therefore, would expect that the process would result in a very close range of particle size in the finished product. I would even go so far as to say that it would be difficult in this process to make granules that have not a close range of size or even to make granules of a relatively large size. You are very much controlled by the need to recirculate perhaps fifteen times the product rate at the beginning of the process to provide the surface necessary.

If you will turn to the subject of Mr. Brook's paper, we are studying there the granulation of materials which are initially all solids and which are brought together by wetting and agglomerated. In this process fines are produced necessarily and they have to be absorbed by returning them to the beginning of the mixing process, and they become an embarrassment.

Mr. Brook's paper shows a method of illustrating the size distribution of a granular fertiliser, and this is the type of diagram which you can see in Figure 13: Curve 1 indicates that such and such a proportion of material would pass a screen of particular size, and it gives a cumulative quantity passing the size of screen. This is plotted with a logarithmic base. If we produced it to the right of its present position it would represent material geometrically similar.

Curve 1 in the paper results from using 7.15 per cent of moisture and it gives a mean size; that is, 50 per cent of the material passes through 1.7 millimetres. As the water content is increased to 7.6 - that is a very small increase - the mean size increases to 2.7. If the water is increased to 8 per cent - still only a smallish increase - the mean size becomes 4.7. 1.7, 2.7, 4.7 for an increase in water from 7.15 up to 8. So the mean size is very susceptible to the amount of water added.

Another feature is that as the curve is moved to the right by adding water, so the shape alters. These are not geometrically similar, and the best curve is the one having the steepest central portion, that is the best curve in the series. As the size increases further, so the slope becomes more horizontal, which means that a smaller quantity of fertiliser is produced within the wanted size range. This method, I think, should be used by those who are studying the "granulability" if I may use that word, of materials, and one should not start with a preconceived idea of sizes to which you intend to work.

Let us put this another way: a material which has, say, 80 per cent of its total between, say, a 3 to 1 ratio of size will give a presentable looking product. I suggest that if you were to work with the third slope, your 3 to 1 ratio would result in a very much smaller vertical intercept. In other words, you have a smaller amount of product available for the first passage.

Obviously, from the manufacturers' point of view, curve 2 is the one to work on because the maximum product will be made within a given range or size - say, 3 to 1. That is why we tend to work to that in practice.

Now on the contrary - I must bring this a little outside the first paper, and go on rather to the third one - we have to consider not merely the production rates, but we have to consider whether or not during storage it is advantageous to make granules. This is not important on the economic side, but it is important to the manufacturer and the user alike.

The third paper in the series, Mr. Brook's, touches on the hardness of granules in relation to moisture content and shows that over a certain range the relationship is more or less linear. He also draws a conclusion, I think, that hardness and the undesirable quality of caking may be related. I think it is also generally understood by workers in this field that moisture content seems to relate fairly well to caking, so that you may have some triple relationship there between hardness, caking and moisture content. Possibly this would be fruitful for discussion.

From the manufacturers' point of view, I think that on size of granule itself, it would be an advantage to make large granules to reduce the amount of caking, but, on the other hand, the drying of these large granules would be more difficult so that you might expect a higher moisture content which might perhaps vitiate the advantage of a larger size.

Another aspect in which size comes into account is in the application. This Conference has not taken account of the types of fertiliser appliance. I have reason to believe that the accuracy with which fertiliser can be applied is improving as manufacturers improve their machines: they have probably reached a stage of progress which is somewhat ahead of the requirements of the agronomists. Dr. Cooke of Rothamsted has made a plea for improving the reliability of machines rather than obtaining high accuracy. In this respect I submit that the sizes of granules which we are customarily making are quite reasonable choices.

If I may now just summarise the points, the manufacturer is the person who will decide the size of granule for a number of practical reasons. These are, firstly, to exclude dust: obviously this is a general nuisance and contributes to all kinds of caking and other handling problems. The size of granules made will tend to be on the small side, and the lower limit of size will be governed by the size of the screening device which it is practical to operate. I suggest about 1 to 1½ millimetres.

The upper limit will be three times as large, merely from the point of view of satisfying the fertiliser appearance, and a further point which I have not yet mentioned, to reduce segregation. Segregation leads to variation in chemical analysis of the type of fertilisers made by the process described by Mr. Brook.

The mean size, or the average size, will tend to be defined by these two limits and there is no indication from the agronomist that we need to raise it any more. The exception to this will be the old slurry process starting from liquid on the basis of the

triple-superphosphate granule that I described.

If I may just add one further point which I touched on in a question this morning, I wonder whether sufficient importance has been given to the possibility that powder fertiliser would be as effective as a granular fertiliser if placed in bands and not broadcast. This might cause us to think carefully about the reasons for granulation.

DR. R. STEWART (United Kingdom): Mr. Chairman, Gentlemen, I have now to give the agronomic reasons for granulation; or should I say that I have to state the agronomic reasons for and against it?

One must recognise that the importance of granulation is bound to vary in different countries. Those countries which use most of their fertilisers in the form of straight fertilisers will not be very much concerned with granulation, with the exception of the possibility of using granular superphosphate in the place of ordinary powder. Those countries which are in the habit of using most of their fertiliser in the form of mixed N-P-K compounds are very definitely interested in this subject of granulation.

My second point on this - and this, I think, is perhaps the most important - is that one cannot speak of granulation in general terms - one can only speak of the granulation of a particular fertiliser or fertiliser mixture. The results which are obtained by the use of granular forms of one material will not necessarily apply to the use of a granular form of another material. I would like to suggest that there are at least four separate possibilities. We have, first of all, straight superphosphate; secondly, straight phosphate containing an insoluble form of phosphate such as dicalcium phosphate, either anhydrous or, usually, dihydrate; thirdly, N-P-K compounds containing soluble P_2O_5 ; fourthly, N-P-K compounds containing either all insoluble, or at least some insoluble, P_2O_5 . The advantages or disadvantages of granulation are quite likely to vary between those four categories.

The only paper from the agronomic side that we have before us this afternoon is that by Mr. Simpson. You will find that he deals with the results of experiments carried out by I.C.I. at Jealott's Hill, comparing granular and powder phosphates. He reports experiments comparing the effect of granulation of both hydrated and anhydrous dicalcium phosphate, and he reports experiments comparing granular and powdered nitro-phosphates containing some insoluble P_2O_5 . Mr. Simpson's paper states the results of those experiments in general terms and particularly whether there was a significant difference between the various materials. One is entitled to ask what is the magnitude of the difference one can expect between, say, a granular form of the material and a powder form.

In the time available, I have not been able to look out any extensive data on this point but just before I left England I got the preliminary results of one of the experiments carried out by our own research department this year. This was an experiment in which a granular N-P-K compound was applied to the surface of established grassland. Run-of-factory material, that is normal material, was used and also five size fractions separated from that factory-made material. The sizes were 3.18 to 4.75 for the largest; 1.68 to 3.18; 1.00 to 1.68; 0.5 to 1.00; and less than 0.5 m.m.

In one experiment the following yields of dry matter from one cut of hay were obtained; for the above size fractions - 52.1; 49.4; 55.9; 58.1; and 49.4 cwt. per acre. This was a randomised plot experiment and the statistical analysis shows a significant

difference of 7.2 hundredweights per acre. That means that there was no regular variation between the maximum and minimum in size, but the difference between the lowest yield and the highest yield was 8.7 hundredweights per acre of hay and was significant.

That is of very definite economic importance to the farmer. At current prices that would be somewhere in the region of £5. to £6. in terms of English money if he were selling that hay. It is possible to get differences of the order of magnitude of 10 per cent or more through the use of different granule sizes, and these are economically significant.

This experiment also brings forward another point, and that is how we should assess the efficiency of the fertiliser. In most cases one is content to take the yield of the crop, sometimes expressed in terms of dry matter per acre or per hectare. In this particular case, where the fertiliser was being applied to the grassland, both the yield and the quality of the grass were of importance to the farmer. When the crude protein determinations were made on the grass samples from these various treatments, the yields came out in rather a different order. The yields of crude protein were 3.52, 3.73, 3.96, 3.63 and 3.22 cwts. per acre. The size which gave the maximum yield of dry matter was the 0.5 to 1.00 mm. size. The size which gave the maximum yield per acre of crude protein was the size above it. The largest yield of crude protein was from the slightly larger material. That, no doubt, was due to the particular effect of the phosphate on the clover in the mixed pasture. Therefore, one has got to be a little careful as to how one should assess the efficiency of the fertiliser.

Mr. Simpson's paper reports a review of the effects of granulation as determined by experiments in a number of different countries. I should like to finish by just briefly summarising the agronomic evidence as far as we know it at present. First of all, as regards class 1, that is, granulated superphosphate or triple-superphosphate as such; I think the evidence comes to this, that granular form is not always better than the powder form, but is very seldom inferior. It is frequently better on acid soils, particularly acid sands such as Professor Fruhstorfer is working with in North Germany. It may show up special advantages with regard to certain crops. There is some evidence that crops which have a short growing season or a poor rooting system require their phosphate early in their growth cycle, and if that is not available, the yield suffers. If those are grown on a soil with a high fixation power, there is some evidence that granulation is a definite advantage. Therefore both the type of soil and the type of crop you are working with may determine the value of granulation.

With fertilisers of the second category, that is, either granular dicalcium phosphate itself or superphosphates which have been highly ammoniated so that most of the phosphate has reverted to that form the evidence as far as it goes, is that granulation is almost always a disadvantage and that the maximum efficiency is obtained either with very fine granular material or with powdered material, and when you can intimately mix that fertiliser with the soil.

With regard to the third category, that is, compounds based on soluble P_2O_5 , the position seems to be much the same as for superphosphate. There is no consistent disadvantage or advantage and granule size is, therefore, not of any great consequence.

On this question of size, one would not expect size to be important unless the physical operation of granulation by itself produced a large effect. Since it does not frequently produce a

large effect for this type of material, it is not very likely that size is going to be critical.

With regard to the fourth category, that is compounds containing either some or all of the phosphate in an insoluble form, again the evidence is much as for the insoluble phosphates. Granulation is frequently not desirable. In practice one does not get many N-P-K compounds with all the phosphates as insoluble phosphate. Most of the processes, such as the nitro-phosphate type of process, the ammoniation of superphosphate with a high degree of ammoniation and so on, lead to a compound containing some soluble phosphate and some insoluble, and it is quite a tricky point to decide agronomically what is the desirable proportion of water soluble P_2O_5 in a compound of that category.

I have only two further small points to make; the first is with regard to the hardness of the granule. Mr. Brook's paper has dealt with the problems of manufacturing hard granules at low moisture contents. One must admit that the agronomic experience in this direction is, at the moment, quite negligible. It seems a fair guess to assume that hardness is not going to be very important unless there is formed on the surface of the granule a surface skin which impedes diffusion of soluble constituents from the inside of the granule.

The final point regarding physical properties is one on which again we know very little, and that is the speed with which the granule breaks down in contact with the soil moisture. One might call it the slaking property of the granule. There is a little evidence that for compounds of this type - that is, containing insoluble P_2O_5 - it is an advantage if that granule immediately or quickly slakes in contact with the soil moisture, in that it is no longer a granule and there is a larger surface of the insoluble material exposed to the plant roots. Therefore, the breakdown of the granule in the soil may, under those circumstances, be a factor which might have some agronomic significance.

I have confined my remarks to the agronomic aspect, but, in conclusion, there are one or two purely agricultural aspects of physical properties with which you are mostly familiar. Farmers, on the whole, prefer to handle a material which is not dusty; they prefer to handle it in granular form rather than in powder form. That by itself could be sufficient justification for providing the material in granular form.

There is also the question which was mentioned, I think, by Mr. Sherwin in his remarks, of the ease of drilling, the manner in which the fertiliser will pass through the farmer's machines for application. We have the extreme case of the granular ammonium nitrate which is produced in the United States and Canada, which is produced by a different type of granulation process and gives a very nearly spherical granule of very uniform particle size. With many agricultural drills that type of material of uniform size and smooth surface flows through the drill much too rapidly, and it is difficult in the field and on the farm to control the rate of application. That does not apply to the same extent with granular compounds made by the other processes of wetting and aggregation and so on, because they are mainly slightly angular and have a range of particle size.

THE CHAIRMAN. Thank you very much, Mr. Stewart.

I am sure we are all very obliged to our introducers, Mr. Sherwin and Mr. Stewart, for what they have told us. This, together with the papers of Mr. Brook and Mr. Simpson, forms an excellent base for the coming discussion. Perhaps it would be

useful to say that we should in this discussion postpone the pure technical questions and perhaps confine our remarks to the interest of agriculture in the granulated fertiliser, such questions as the agronomist can put forward to the technical people, and vice versa.

PAPER NO. PA.145

EFFECTS OF PARTICLE SIZE ON THE EFFECTIVENESS OF FERTILISERS by
D.E. Simpson (United Kingdom).

MR. L. DIDIER (North Africa) (Interpretation): Mr. Simpson, on page 7 of his paper, says: "In the case of nitrophosphate and dicalcium phosphate (Jealott's Hill experiments), there was a tendency for the response to these fertilisers - in terms of yield and uptake of P_2O_5 - to decrease with increasing particle size. Not unexpectedly, the pH of the soil appeared to have a marked effect on efficiency, these fertilisers being much less efficient on calcareous than on acid soils". I should like to refer to the experiments carried out in Tunisia for three years on calcareous soil with an alkaline pH of 8, where the granular superphosphate except when ground to 1 mm. or below, was inferior to the powdered superphosphate. On the contrary when the soil was podzolic, the granules were better than the powder. The explanation was provided by the agronomic service. "In the clay calcareous soils with an alkaline pH, the sesquioxides in a precipitated form are harmless. They are, on the other hand, drowned in a very large quantity of limestone, it is the latter which plays a role. It combines with monocalcium phosphate to give dicalcium phosphate water-insoluble but which plants can take up. Whether you make big or microscopic granules, you will always obtain available dicalcium phosphate. Therefore, the advantage of granulation becomes non-existent."

MR. D.E. SIMPSON (United Kingdom): Mr. Chairman, Gentlemen, the conclusions from my paper were based largely on the work done at Jealott's Hill, although they conform pretty closely with the conclusions arrived at by Sherman and Hardesty. I do not think there was any particular difference between granular and powder superphosphate. As you will have seen, they were carried out on a range of soils, calcareous, neutral and acid and there was no significant difference, I do not think, between the different types of soil. In fact, in experiment III the up-take of phosphorus was significantly less from superphosphate on neutral and acid soils, but not significantly so on calcareous soils.

We do have a thing called experimental error coming in, which I think Dr. Stewart referred to, and while I am on my feet, I should like to thank him very much for his very full and adequate exposition.

I am afraid I have not with me all the mass of detail on which this paper was based, so that I cannot give figures as to the differences between a powdered and granular superphosphate. I appreciate his feeling that some of these differences, although they are not significant, may carry a trend in a certain direction. We can only make these significant if we carry out a sufficient number of trials, but I think I can say, speaking from memory, that there was not even a trend in the Jealott's Hill experiments between powdered and granular fertilisers.

I should like to emphasise that obviously these experiments which I quoted do not cover every soil or type of soil, and it is known that the soil characteristics can have an important influence on phosphate up-take, apart from other things such as temperature, water supply and so forth. I am not suggesting that the experiments quoted cover all soils.

DR. K.C. SCHEEL (Germany) (Interpretation): Speaking as a chemist, perhaps I am likely to be able to see the difficulties more clearly. One of the difficulties is that, when fertilising with phosphates, one has to take into account the various reactions: the speed with which the phosphoric acid is taken up, and the fixation of the phosphoric acid in the soil.

I should like to refer to a third point, which is the washing out of phosphoric acid from the soil. Although people say that it does not take place, with the aid of tracers it has been confirmed that phosphoric acid is actually washed out of the soil to a certain extent.

The assimilation of plant nutrient depends firstly upon the type of plant, whether the plant has a long period of growth; secondly, upon the living conditions of the plant; thirdly, upon the other nutrient elements; and also upon the moisture, the temperature, the light, etc.

The second reaction - the fixation of the phosphoric acid in the soil - is conditioned by quite a number of circumstances. There is not only the soil reaction but there is some other condition of which, so to speak, we do not even have an inkling. It is also a question of whether a soil is colloidal, and this depends upon the amount of humic substance in the soil. The fixation of phosphoric acid in the soil also depends upon the temperature of the soil - whether the soil is warm when the fixation proceeds more rapidly, or whether the soil is at a lower temperature when the fixation is somewhat retarded - the moisture content of the soil etc.

The leaching of phosphoric acid in the soil, of course, depends, in the main, on its moisture content, that is, on the weather conditions. In this realm it is somewhat easier to prove that all these various factors exist, but it also depends on whether you deal with the appropriate plants and the appropriate type of soil to be able to say whether granulation is more advantageous than the powdered form of fertiliser.

Even with the few fertilising experiments which I know, my experience is in complete agreement with what various people have said, in particular with the statements by Mr. Simpson. I am of the opinion that if you are dealing with fertilisers which are not water soluble, they act better if very finely granulated or in powder form. From the standpoint of the manufacturer, of course, it is a question of delivering the fertiliser in such a form as is desired by the customers and if the customers want to have granulated superphosphate, naturally you have to supply them with granulated superphosphate.

THE CHAIRMAN: We have now heard a very interesting statement by a manufacturer of superphosphates. I think Dr. Scheel would be surprised if the farmers wish to have the products we make. Perhaps it will be bad for them, but we have to do what they want.

I think perhaps Dr. Stewart would like to comment on this very interesting point of view.

DR. R. STEWART (United Kingdom): I think the only comment I can make is that farmers may prefer the granulated superphosphate for purely physical reasons: they prefer to handle it in that way. If it is not going to give them as good results as ordinary superphosphate, I am quite convinced that, in time they will find it out and they will then go back and ask for the powder. Farmers are not quite so unobservant as they are sometimes made out to be!

I am quite convinced that you cannot continue to sell the farmer something which is against the run of agronomic experience; sooner or later they will find it out for themselves, whether experiments are carried out or not. There may be quite good reasons for their preference for the material in the granular form: they like to handle it in that way.

THE CHAIRMAN: From the remarks of Dr. Stewart, you have confirmation that the position of the manufacturers of fertilisers is very difficult. For the present we have to make everything in a granulated form because the farmers, for the present, wish to have it that way; but we have only to wait some time and they will see that something in the product is not being conveyed and they will change their minds. That is the fate of the manufacturers!

DR. R. STEWART (United Kingdom): I should like to reassure the manufacturers to some extent. I think I said that granular superphosphates may not always be better than powder superphosphates, but they are seldom inferior. Mr. Didier mentioned that on highly calcareous soil in a dry climate the powder material gives a better result than granular material, but I think that is an exceptional circumstance of a very dry climate and highly calcareous soils. That one case need not disturb the general view that for most circumstances granules are no worse than powder. Therefore, if the farmer prefers it that way, I do not think you are going to run very much risk.

DR. K.C. SCHEEL (Germany): If we were to advise the farmer from the agricultural-chemical point of view, we would almost always have to advise him to use straight fertilisers instead of compound fertilisers. As far as mixed fertilisers are concerned, the farmer is always very pleased to have a granulated fertiliser, particularly in that part of Germany where I come from. It is very often windy there, and at one time, when we were trying to supply a farmer with as fine a superphosphate as possible, what happened was that the wind carried his superphosphate on to his neighbour's field and the farmer himself did not get the superphosphate which he had bought. I think that the remarks on granulation would also apply to potash salts and other salts.

M. N. CHARLIERS (Belgium) (Interpretation): I thought I read in Mr. Simpson's paper that the addition of superphosphate to slightly soluble phosphatic fertilisers eliminated the negative effect of granulation. May we conclude that it is the free acid in the superphosphate that makes the other phosphatic fertilisers mixed with it more soluble?

MR. D.E. SIMESON (United Kingdom): It was really a quotation from an American paper on the assimilability of granular dicalcium phosphate. It is on page 3, and in the last part of the paragraph it says that the addition of the water-soluble phosphates to fertilisers containing insoluble phosphates, or finer granulation, reduces the disadvantages of the dicalcium phosphate due to the granular state.

I think that is borne out in the Jealott's Hill experiment, to which Dr. Stewart referred, on this slaking effect. If you look at experiment VII on page 7, you will see that, where dicalcium phosphate was pelleted with ammonium nitrate, it was more effective in the pellet form - 3.2 millimetres - than when dicalcium phosphate was pelleted alone. The deduction there was that it was obviously due to the slaking effect. That, I think, is important in the fertilisers of class 4 which Dr. Stewart put on the board, where you have N-P-K soluble plus insoluble.

M. SOUBIES (France) (Interpretation): I should like to say something comparing granulated and powdered phosphatic fertilisers, for at Toulouse we have rather a lot of experience in this comparison between superphosphate and complex fertilisers containing phosphoric acid which is soluble either in water or in ammonium citrate. The

general conclusion is that in calcareous soils granulation gives less good results. For a pH of 6.5 it does not matter if we granulate or not. Below 6.5 it is advantageous if the superphosphate is granulated, but in these conditions, I must say, that it is just as advantageous to use basic slag.

On a calcareous soil with N.P.K. fertilisers, which contain some superphosphate, there is certainly a disadvantage in granulating. Separation occurs, at least as far as we know, with particles of 1mm. Below 1 mm. it is clearly very favourable; above 1 mm. it is clearly less favourable, and if we make particles between 1 - 3 mm. or larger, there is not a very big difference. However, the larger granules give the least good results. But in a calcareous soil, the two cases must be distinguished according to the fertiliser with which we are dealing. There are granular fertilisers which give a less good result, but this is nothing but a delay in the action, i.e. you will get a less good result from granulated fertiliser in the first year, but you will do better in the second year and better still in the third year than with powdered superphosphate. All in all, this causes a different distribution, but the increase in yield remains at the same total. There is, therefore, no great inconvenience in granulating; we must simply inform the farmer that he will have a more persistent action even if it is slower in the first year.

But in the case of certain other fertilisers, it does not work this way and we are presented with rather a knotty problem. For certain granulated compounds, we obtain in the first year results which are less good than with powdered superphosphate, but which do not improve in the second and third years. Here, we must ask ourselves what is happening.

I am going to give you, broadly, an outline of the results. When we compare the effect of superphosphate, that is the increase in yield obtained by an application of superphosphate on a soil which was originally very poor - we generally get a falling off in the increase which is as follows:

	80	in the first year
about	15	" " second "
	5	" " third "
	<u>100</u>	Total

For certain complex fertilisers - which I would call "good" - we get:

	65	in the first year
	25	" " second "
	10	" " third "
	<u>100</u>	Total

The totals are the same or there is no significant difference. But for certain others, we get, simply:

	35	in the first year	or	25	in the first year
	10	" " second "		5	" " second "
	5	" " third "		3	" " third "
	<u>50</u>	Total		<u>33</u>	Total.

when the fertiliser is granulated.

If the fertiliser is not granulated or if it is applied to acid soils these differences do not occur. This is not due to the phosphate - it is due to the combination of phosphate and granulation.

In conclusion, should we granulate or not? - this is the question which manufacturers ask themselves. Yes, granulate if you wish. For

a soil pH of 6.5 for superphosphate it does not matter. Below this, it would be better to granulate; above this it would perhaps be slightly disadvantageous but it only gives a delayed effect. But if you are making compound fertilisers, do not granulate anything. There are some fertilisers which can be granulated without harm and others which cannot. I should like to ask the chemists a question on the explanation of the lack of effect of certain complex fertilisers rich in calcium. Is it that (I ask a question to which I know no answer) during the first years, in the interior of the granule, the most soluble part of the phosphoric acid disappears - thus enriching the granule in calcium - and is there a change of the phosphoric acid from a form containing little calcium to forms which are very rich in calcium and consequently of lower activity?

M. P. FLEURY (France) (Interpretation): I do not intend to reply to this question but I should like to make two small remarks on what has been said about granular fertilisers. In certain cases the manufacture of complex fertilisers nearly always automatically includes granulation. This is certainly the case for fertilisers made by reacting phosphate rock with nitric acid where the primary product is a slurry. The simplest method of drying this slurry is to recycle the fines and to granulate. Obviously it would be possible to grind finely the granules after that, but we would, I think, have difficulties because of caking with the usual composition of these products. On the other hand after the remarks by Dr. Stewart it is very disturbing to see that certain fertilisers containing insoluble P_2O_5 have a lower efficiency when granulated especially in the case of complex fertilisers made from nitric acid, where the surplus calcium is treated as carbonate and not as sulphate, because these fertilisers derived from nitric and carbonic processes end up as mixtures of ammonium nitrate, dicalcium phosphate and calcium carbonate and they contain hardly any water-soluble P_2O_5 . In this way it would be very difficult for the manufacturer if there is no soluble P_2O_5 . I should also like to add that the agronomists compare granulated fertilisers and powdered fertilisers; if the granulated fertiliser is well-defined by the size of its granules, the powdered fertiliser is not well-defined. Agronomists usually take, for experiments in pots or in the field, a finely ground fertiliser. In commerce, on the contrary, if we sieve an ordinary superphosphate or a mixed fertiliser we observe that there is an important residue. Powdered fertilisers are thus practically a heterogeneous granulated fertiliser.

DR. R. STEWART (United Kingdom): I should like to draw attention to the very extensive work done in Holland some years ago by Dr. Mulder on the agronomic efficiency of a form of nitro-phosphate. He carried out numerous and extensive experiments, both in pots and the field, to compare material with different granule sizes, and also with different degrees of water solubility. The normal product had a low water solubility but by modifying the process, an increased water solubility could be obtained. The results they found were in general agreement with those reported by M. Soubies, in that in alkaline soils the nitro-phosphates were less effective when they did not contain very much water-soluble P_2O_5 , but there was a reasonable effect on soils with a pH round about 6 and below.

M. N. CHARLIERS (Belgium) (Interpretation): In reply to the question put by M. Soubies I should like to make a suggestion. In the process of granulation is it not that we work with temperatures which would allow the dicalcium phosphate with two molecules of water to become anhydrous. This morning our attention was drawn to the great difference between the efficiency of these two forms of P_2O_5 . It is perhaps partly an explanation of the question put by M. Soubies.

M. SOUBIES (France) (Interpretation): I do not think so. I have not found any confirmation of the explanation given by M. Charliers. I do not think this is the case for we have extracted phosphate from each of the products which were not satisfactory and when they were not granulated they worked very well. In reply to M. Fleury I must say one thing: it is quite definite that we must granulate phosphate made with nitric acid. What I must emphasize is that it is necessary to know what we should granulate.

M.H. RICHARD (France)(Interpretation): I should like to ask M. Soubies if in his experiments, he was able to vary the amount of rainfall or, at least, the moisture content.

M. SOUBIES (France)(Interpretation): No. These experiments were carried out in pots and the amount of water was the optimum. We watered the plants each morning.

M. P. FLEURY (France)(Interpretation): With regard to the explanation given by M. Charliers on the subject of the final formation of anhydrous dicalcium phosphate, I do not think it occurs in well-made granulated fertilisers, because, as a result of the French method of analysing the P_2O_5 with alkaline citrate of ammonia, it is seen that there is a deficiency of alkaline soluble citrate P_2O_5 . The drying temperature is closely controlled so that the dicalcium sulphate is not dehydrated.

DR. B. RAISTRICK (United Kingdom): I wonder if I could ask M. Fleury what proportion of his dicalcium phosphate is present in his nitro-phosphate as dihydrate, and how he knows?

M. FLEURY (France)(Interpretation): In fact, the method of analysis does not distinguish between anhydrous dicalcium phosphate and tricalcium phosphate or even unattacked phosphate in the insoluble fraction. What is important, from the commercial point of view, in France, is that phosphates are sold on the basis of P_2O_5 soluble in ammonium citrate. The insoluble part is of less value and consequently every endeavour is made to keep this insoluble fraction to a minimum.

THE CHAIRMAN: Perhaps we could now finish the discussion of more agronomic things. I should like to hear whether you have some remarks on the implications of Mr. Brook's Papers.

PAPER NO. LE/761 - GRANULAR COMPOUND FERTILISERS by A.T. Brook (United Kingdom)

Mr. P. CRAVEN (United Kingdom): Mr. Chairman, I have two questions which, I think, are connected. One concerns the second paper, whether or not Mr. Brook has done any work to determine what effect temperature has upon the moisture/hardness relationship; the second concerns the first paper, whether or not he has gone into the question of breakdown within the drier. He mentions the fact that within the drier you get a considerable amount of granulation occurring, but he does not mention breakdown, which I feel would also occur. There are two processes, one in which you are drying the granule and thereby reducing the elasticity of it; secondly, you are increasing the temperature and thereby you tend to increase the elasticity. These two things occur at the same time.

MR. A.T. BROOK (United Kingdom): With reference to Mr. Craven's first point, the three moisture contents given as ordinates are really a measure of the temperature to which a granule is raised when dried. That is, in these particular formulations of fertiliser, the moisture content is very definitely related to the temperature to which it is finally dried within quite close limits for a given drier. Therefore, the curve would equally well serve under a particular set of conditions if the ordinates were granule temperature ex the drier.

On the second point regarding breakdown, I cannot say that we have brought this point out very thoroughly, except indirectly in that we now carry out dust measurements in the gases which are taken from the drier and the cooler separately. We have a method for measuring the true dust content of the gases over quite long

periods of time: we can say quite conclusively, from the amount of dust we collect from the drier gases, that the breakdown in the drier must be quite negligible.

Dr. R. KAACK (Germany) (Interpretation): I would refer to the granulation of fertilisers and to super compounds in particular. I would stress the existence of the liquid phase: I am of the opinion that the amount of water can be reduced by using water vapour (or hot water) instead of water as such. I was wondering whether Mr. Brook had made some experiments with water vapour instead of water.

Mr. A.T. BROOK (United Kingdom): We have done quite a lot of work in using water vapour i.e. steam. The effect is not quite so noticeable or so different from the use of cold water as we would have expected. The amount of liquid phase required is a rather difficult matter to determine. If one employs steam or, say, hot air for granulation, the final moisture content of the material from the granulator is definitely lower, but in the passage through the granulator much moisture vapour has come off the material; it must come off by virtue of the high temperature. The addition of water vapour or hot air raises the temperature substantially at the beginning of the granulator. I do not think, frankly, that there is an awful lot of difference in the moisture content (i.e. liquid phase) at which granulation takes place at the beginning of the granulator whether you use cold water or water vapour.

PAPER NO. 14/762 - MOISTURE CONTENT AND HARDNESS OF GRANULES
by A.T. Brook (United Kingdom)

Mr. I.A. BROWNIE (United Kingdom): I should like to ask a question about Mr. Brook's second paper on the hardness of granules. He mentions on page 2 that he used a pressure of 150 pounds per square inch to achieve the breaking force. I think, from mental calculation, that would correspond to a very high stack of one hundredweight bags; indeed it would probably be several hundred. If he had used a smaller breaking force, then the graph which he would have obtained would, I believe, lie somewhat higher up on the Y-axis. Therefore, he would have a difference or possibly not an intercept when he drew from 1 per cent moisture across the graph. If we assume then that on a low stack of fertiliser bags, there is insufficient pressure to cause material breakdown of the granules, we come back to the original statement on page 1, that he does believe that certain characteristics are related to the hardness of granules. I wonder if, in the absence of a breaking force, he believes that the plastic nature or plastic deformation of granules is responsible for caking. If he does believe that, does he also believe that the plastic deformation occurs between 1 per cent and 3 per cent moisture? If so, has he any way of measuring this plastic deformation?

MR. A.T. BROOK (United Kingdom): With reference to Mr. Brownie's first point on the high pressure, I agree that it does seem ridiculously high, but this test was a scratch test largely to see if we could find some correlation between moisture and hardness. It was really the third of a number of tests we devised: right from the start it gave better results and we stuck to it. We found very quickly that if we were to get anything to measure in connection with high dried granules - that is, granules dried to a very low moisture content - it was necessary to have extremely high pressures to cause any degradation at all. The granules are so hard that pressure corresponding to normal pile heights would not have any effect on them. We have just chosen a pressure which would give some dust to measure. I agree that the curve would have been a different shape and probably would be more interesting in accentuating the hardness between low and high moisture granules if we had chosen a rather lower pressure.

With regard to the plastic deformation, we have not actually studied this problem, but I should think an apparatus very similar to the type we used for these tests, in which one had a weighted piston on top of the cylinder, would be the type to follow. We had a test apparatus some years ago which was used for measuring the caking of fertilisers, and it was, in effect, something along those lines: it was a cylinder of about 2-inch diameter, 6 inches high, filled with the granular fertiliser and with a weighted piston on top. We did notice that the piston went down quite considerably after a few hours with pressures of the order of a normal fertiliser pile: that is, 15 to 20 pounds per square inch. I think that test would show some plastic deformation of a 3 per cent moisture compound as against a 1 per cent, based on what we now know of the two materials separately.

MR. A.I. COLEMAN (United Kingdom): Mr. Chairman, there appear to be some common elements arising from these discussions both in regard to the agronomic and technical discussions. The agronomists have evidently carried out a lot of work and produced many results with enormous differences in them. When these are examined - the leading speakers are concerned mostly with finding reconciliation between these differences - it becomes quite evident that there are more things which affect the results than are necessarily recorded in the papers.

I suggest that the results are not necessarily in conflict. I suggest that we should endeavour to standardise our examinations more than we have in the past. Each set of results is probably perfectly true for the precise circumstances under which they were performed. These considerations apply equally well to matters arising out of Mr. Brook's paper. He refers to a test apparatus in which he applies several conditions and obtains different results concerning the influences of the various factors on granulation. I think it would also be true to say that there are as many different ideas on how good granulation may be affected as there are granulation plants, and even sets of operators to work those plants.

The absence of standard methods and standard procedures which are evident in the agronomic experiments, are equally evident in the experiments on production. Mr. Brook is, I am sure, perfectly aware of such factors as dimensional similarity. His experiments do not reveal, nor do I imagine it is possible to ascertain, the effect of linear dimensions upon the various results that he reports: but the similarity goes further than dimensional, it is concerned with every single fact: it concerns the set of observations being made, the temperature, the geometrical feature of the apparatus, the velocities, the atmospheres, the temperatures of the water: even the material being studied can itself affect the results.

One of the few deductions we may derive from this Conference is that different circumstances produce different results. I suggest if we are anxious to ascertain the fundamental truths, we must, as Dr. Raistrick said this morning, standardise on dicalcium phosphate and standardise on methods of procedure in general.

M. L. DIDIER (North Africa)(Interpretation): On the subject of the anomalies found by M. Soubies, I should like to put the following question to him: Has he analysed, in the soils he uses, the iron and aluminium complex which could play a great part in this? What strikes me is that the same granules which are ground and powdered work well whereas granules give poor results.

M. SOUBIES (France)(Interpretation): They are calcareous soils with very little iron. The main reason seems to be the kind of reversion of the soluble form of phosphate in the granule into a less soluble one. It is a specific effect of granulation.

M. P. FLEURY (France)(Interpretation): I should like to ask whether you have any evidence of the influence of the acidity of the mixture on the granulation. In my experiments I arrived at the conclusion that with N-P-K mixtures containing superphosphate the acidity promotes the granulation, but if the mixture is acid after being granulated, the product shows a tendency to set. Also, this question applies when ammoniated superphosphate, which is neutral is used.

MR. A.T. BROOK (United Kingdom): My experiments as shown in this paper, do not give any information on the point which Mr. Fleury raises, but we have done other tests which, without being quite so thorough as some of those we have reported, do confirm that if one relates the free acidity to the freshness of the super, granulation is better with fresh super than old, but this may not be due entirely to the amount of free acidity. With various fertilisers made from supers having different acid rock ratios, but of equal age, we did find that granulation was better with a high natural free acidity.

With respect to the second part of the question, the effect of the free acidity on the subsequent setting, I think that is a rather more involved point. I should not like to answer it here, since I feel setting is much more concerned with moisture content.

MR. I.A. BROWNLIE (United Kingdom). I have just one small question on Mr. Brook's paper on granulation. On pages 10 and 11 he deals with experiments he has done with a by-product ammonium sulphate as opposed to synthetic, the former being a fine needle and the latter being a larger crystal. I should like to suggest to Mr. Brook - possibly he has done this already - that a better way of comparing the effect of the particle size of ammonium sulphate would have been to take different stream fractions of synthetic ammonium sulphate, because when you do examine a number of types of ammonium sulphate of different sources, the effects of impurity are quite marked in the results that you get.

MR. A.T. BROOK (United Kingdom): Mr. Brownlie raises a very interesting point in respect of the possible impurities in by-product sulphate. In fact, we did at one time consider that the impurities in this material were really responsible for the poorer granulation which we got at that time, as against the use of synthetic sulphates made from synthetic ammonia. But we did, in fact, carry out the type of test which Mr. Brownlie suggests. We carried out a very large number of granulation tests in which the sulphate was graded in close size ranges, starting from something of the order of 60 BSS screen with 1 screen mesh difference; that is, 60 to 52, 52 to 44, and so on, both for by-product and for synthetic sulphate. Much to our surprise, the water requirements and the efficiency of granulation using the two sulphates varied very little indeed for a given size range. In each case rather more water was required by the by-product sulphate, and the granulation was not quite so good, but these differences were small compared to the effect of the particle size. We may be wrong here, it may be that certain impurities have some effect; but I would say from our own tests that it is the particle size of the sulphate which is paramount.

THE CHAIRMAN: It is nearly time to adjourn the Conference for today. Before finishing, I should like to make a few remarks on what Mr. Coleman has said. Of course, there is a paramount significance in standardising our methods, our terms and all the things we are speaking about; I think we agree on that. On the other hand, technical development is proceeding so fast, that I think standardisation and technical work must go hand in hand. Therefore, of course, we may have many cases where we have not reached the stage of standardisation. It is for that reason that we have this meeting here, in order that we may have the opportunity to talk about the different methods and have the chance to standardise our methods. But I do not think we can place standardisation as number one and the normal technical experiments as number two: they must go hand in hand, and I hope we have learnt a lot about this through the discussion today.

I would repeat my thanks to the authors today for their interesting papers. I would also thank our two introducers and all the gentlemen who have taken part in this very interesting discussion.

We meet again the day after tomorrow at 9.30 a.m. Thank you very much, Gentlemen.

THE INTERNATIONAL SUPERPHOSPHATE MANUFACTURERS' ASSOCIATION

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JOINT TECHNICAL-AGRONOMIC CONFERENCE

LAUSANNE: 24th-26th September, 1956

Report of Discussions

Morning Session 26th September, 1956.

Mr. D. J. BIRD (United Kingdom): I will now call you to work, Gentlemen, on the third section of our papers. The problem that we are going to discuss this morning is one which I feel personally is of major importance to our industry, namely the effect, from the agronomist's angle, of the more concentrated fertilisers which are now being produced and offered to farmers.

The Chairman for this morning's discussion is Mr. Dior, and I will now ask him to take charge.

Before Mr. Dior assumes the Chair, I should have welcomed here this morning personally and on your behalf Mr. Gallay and his colleague, Mr. ~~Stall~~ Stall.

In the Chair: Mr. J. Dior

Mr. J. DIOR (France) (Interpretation): First of all I should like to thank Mr. Bird for the honour he did me when he asked me to be Chairman of this session. Without further delay, we will begin our discussions, and I will call upon Mr. Fleury to speak.

Mr. P. FLEURY (France) (Interpretation): The papers in Section 3 which we are to discuss to-day deal with a subject which, although it is older than that of radio-elements, nevertheless still contains unexplored details. Ever since the time when chemical fertilisers were introduced to practical agriculture, we have only expected them to supply the plant with three elements which are indispensable to their development - nitrogen, phosphorus and potassium.

At the present time in most countries, if we do not count lime which may only be sold as a by-product, these three are the only elements which the fertiliser manufacturer may mention on his labels and sell to his customers.

Everyone to-day, however, admits that the Trinity "N.P.K.", if it is necessary, is far from being sufficient. Many other elements have been added, which are classed, according to HOMES as "Construction" anions and "Catalytic" cations; according to ARNON as macro-nutrients and micro-nutrients, and in a more general way, as elements acting at a high rate i.e. besides nitrogen, phosphorus and potassium, sulphur, magnesium and calcium, and trace elements which act in very small quantities amongst which the principals are: iron, copper, zinc, manganese, boron and molybdenum. We could add cobalt to these, which, although it is not indispensable to plants, is needed by animals; thus it is necessary that the animals find it in the plants on which they feed.

Of these elements only boron has been commercialised by the fertiliser industry which considers it more as a medicine for the treatment of heart-rot in sugar-beet.

Therefore under the general heading "The importance of Nutrient Elements other than N.P. & K., and the consequences of their reduced availability through the production of more concentrated fertilisers" we have four papers dealing with two of these elements: sulphur and manganese.

First of all we have a paper by Messrs. Charliers and Carpentier on sulphur which gives a detailed review of the connections between this element and soil, plants and even the animal kingdom; the work is in some respects confirmed and supplemented by Prof. Fruhstorfer's paper and the results of his experiments. These papers show the technician the essential importance of sulphur in the use of mineral fertilisers, and prove that this element must take its place with phosphorus in fertilisers; this is a conclusion which superphosphate manufacturers must be pleased to hear confirmed definitely once again. Since Mr. Charliers and Mr. Carpentier have shown the efficiency of the gypsum as a sulphate fertiliser, I think it would be useful to mention that considerable quantities of gypsum are to-day discarded for lack of use by makers of phosphoric acid by the wet process. Besides this being a real waste of sulphur, the gypsum obtained by precipitation is in a particularly active form, as, in addition, it contains small quantities of P_2O_5 which escaped the attack, and part of the trace elements which are contained in the phosphate rock used. I think that in Germany, before the war, this product was currently sold on the market as phosphogypsum. It would be desirable that the value of this product as a sulphate amendment should be made evident and that the sulphur and the calcium which it contains should be returned to the soil rather than actually wasted as it is now.

There are also two interesting papers on manganese, one by Prof. Fruhstorfer, which points out the efficiency of the association of manganese salts and superphosphate and the usefulness of this fertiliser in soils lacking manganese, the other by Mr. S. Larsen which supports the argument of the former, while giving another hypothesis on the mechanism of the manganese-superphosphate interaction.

Leaving our colleague Mr. Poll to discuss from the agronomic point of view the conclusions and hypotheses of these four papers, I should like, as a technician, to bring the views of the manufacturer of fertiliser to bear on this question which becomes more important as the scale of nutrient elements is enlarged.

The problem as a whole is as follows: for a variety of reasons - most of them economic - there is a tendency to manufacture more and more concentrated fertilisers, and in consequence their composition is becoming more and more that of pure products; ammonium nitrate, urca, ammonium phosphate, enriched potassium salts are chemical products which only contain small quantities of other elements, concentrated superphosphate replaces ordinary superphosphate and in the United States it has been proposed that phosphoric acid be applied directly to the soil as well as anhydrous ammonia and concentrated ammoniacal solutions.

These practices may, in the long run, lead to a shortage of secondary elements by a double mechanism. On the one hand these fertilisers do not return to the soils the quantities of the elements which the plants take up, and on the other hand phenomena of interaction or of toxicity by breaking the equilibrium can occur, caused by repeated large applications of certain pure elements.

Meanwhile certain fertilisers return (free of charge to the farmer) other elements than those which he bought originally. Ammonium and potassium sulphates contain important quantities of sulphur, but in France we use more nitrate of ammonia and potassium chloride; certain potassium salts are rich in magnesium, in sodium and sometimes in excessive quantities, in chlorine; certain basic slags have high manganese contents, and all are rich in iron. Complex fertilisers made by reaction between nitric acid and phosphate rock contain secondary elements of phosphate rock. Finally, superphosphate

which of all fertilisers is undoubtedly richest in 'secondary' elements contains in addition to a large proportion of sulphur and calcium all the trace elements contained in the phosphate rock from which the super is made. To these must be added those impurities which the sulphuric acid, used in its manufacture, contains.

Is this sufficient? Some people think so. Thus we have been able to read in a recent French technical review an article by Vergnaud, where the author endeavours to show that systematic application of secondary elements or trace-elements to cultivated soils was, for the most part, useless, since manure, fertilisers and especially superphosphate contain sufficient quantities of these.

This might be excessive optimism. Vergnaud considers the actual presence in superphosphate of most of the elements which are found in plants, but is there a sufficient quantity of them? Limiting myself to superphosphate, in which we are all especially interested, it is possible, thanks to analyses recently carried out both by colorimetric and spectrographic methods by Vigier and Tridot of the Comptoir des Phosphates de l'Afrique du Nord, to calculate the amount of secondary elements to be found in superphosphate according to the place of origin of the phosphate used in its manufacture. Consequently we can estimate the quantity of these elements which an average mineral fertiliser dressing gives to the soil, that is 100 Kg/h of P_2O_5 , i.e. 5 to 600 kg. of ordinary superphosphate. We have only taken into account, when ascertaining these figures, widely used phosphate rock, and not certain varieties which contain large quantities of certain elements (for example, an American phosphate from the state of Idaho contains 2% of vanadium.)

I am dealing only with elements contained in phosphate rock. Sulphuric acid itself can include a little iron, sometimes zinc, when it is derived from pyrites, and amongst the elements useless to plants, there are sometimes important quantities of lead and especially arsenic, and also selenium. (See table attached). We have no information about boron, for the phosphates contain very little of this element.

As everyone knows superphosphates contain fluorine, an element which, although not indispensable to the plant, plays a useful part as an antiseptic and disinfectant in the soil, which may well help to explain the superiority of superphosphate over other phosphatic fertilisers.

Our agronomist colleagues would have seen immediately the disproportion between the quantities of secondary elements other than sulphate, given to the soil by superphosphate, and those which are now used to make up deficiencies in the soil; usually we apply a water solution at the rate of 2 kg/ha of manganese; for incorporation into the soil 10 to 50 kg is necessary, according to Scharrer, with an efficiency which is less certain. For copper 6 to 20 kg, for zinc 5 to 6 kg and for molybdenum, recently commercialised in the United States in the form of sodium molybdate, it is necessary to have 75 g to 1 kg per hectare, and for cobalt 2 kg/ha.

Thus, if superphosphate which might be considered to be one of the fertilisers richest in secondary elements contains so little, it seems inevitable that in the future we shall be incorporating into fertilisers sufficient quantities of the elements mentioned above, and this presents a series of new problems on which to base our discussions.

1. In what form ought these elements to be added? In order to determine this we must study the available forms and the metabolism of these elements. May we not contemplate applying to the study of the physiological role the method which seems to give promising results for phosphorus, i.e. the use of radio-active isotopes?

The range of these isotopes is perhaps sufficiently wide for us to find isotopes for most of plant's nutritive elements, with characteristics suitable for tracing.

2. The results of many agronomic observations seem to be that the incorporation of these elements into the soil is frequently not the best way of restitution; better results are obtained in many cases by spraying saline solutions on foliar plant leaves. Essential elements are also available in this form, and the foliar application has now enjoyed great success especially in the cultivation of fruit trees. Dr. Scheel and Mr. Carpentier spoke of this yesterday in their papers. There may well be a fruitful relationship between these two points.

3. Finally, an essential question for the manufacturer, who has to sell his products, is that the authorities should admit that the secondary elements have a value which should be considered in the price of fertilisers. Messrs Charliers and Carpentier have emphasized this point in their paper on sulphur and their arguments are also valid for other elements when it has been proved that these are useful and necessary. What should be the scale of price increases dependent on the addition of secondary elements? This is an important point which the agronomists might be able to fix for us by indicating the amounts which seem to them to be necessary.

To sum up we must emphasize the value of secondary elements in superphosphate and take them into account in the propaganda for this fertiliser, but we must also recognise that for certain of these elements the content is clearly insufficient.

In certain concentrated fertilisers, made from almost pure salts, the addition of a complement of secondary elements seems to be a thing of the very near future. The quantities to be added (taking it for granted that the maintenance amount would be added regularly to the annual fertiliser dressing) and the methods of incorporation and application should be discussed; however, we shall only be able to touch on very little of this vast subject today.

CONTENT OF SECONDARY ELEMENTS IN SUPERPHOSPHATE

Elements	Content in Super			Quantity of elements added to the soil by 600 kg of super (100 kg of P ₂ O ₅).		
	Min.	Mean	Max.	Min.	Mean in kgs.	Max
<u>Secondary Elements</u>						
Sulphur	-	15%	-	-	90	-
Magnesium	0.036%	0.18%	0.75%	216	1,080	4,500
Iron	0.15%	0.35%	1.15%	900	2,100	6,900
<u>Trace elements</u> P.P.M.					Grammes/100 kg. P ₂ O ₅ .	
Manganese	6	12	45	3.6	7.2	27
Copper	4	15	40	2.4	9	24
Zinc	22	170	260	13.2	10.2	156
Molybdenum	2.2	3.5	4.5	1.3	2.1	2.7
Chromium	60	120	150	36	72	90
Cobalt	1	2.5	4	0.6	1.5	2.2
<u>Toxic or ineffective elements</u>						
Vanadium	40	100	180	22	60	100
Nickel	5	20	60	3	12	30
Zirconium	6	10	20	3.5	6	12

THE CHAIRMAN (Interpretation): Mr. Poll will introduce the subject from the agronomist's point of view.

MR. K. POLL (Holland): I had prepared a brief report on the secondary elements which was sent to the I.S.M.A. office too late and could not be circulated in time. I should just like to give you some general idea of the agronomic problem and also some results of experiments with trace elements. It is obvious that in addition to the three elements, N, P and K there are others which play a very great role in the nutrition of plants namely, the macro-elements, calcium, magnesium, sodium and sulphur; the trace elements, copper, molybdenum, iron, zinc, cobalt etc. This has not always been fully appreciated by the fertiliser manufacturers nor in practical agriculture, although it has been discovered that in certain cases it is necessary that they should be applied.

Assuming that the industry will tend to make fertilisers which are more and more concentrated, it is probable that in the fairly near future there will be deficiencies of these elements in the soil. We run the risk of seeing agricultural production diminish because the soil's fertility is not ever-lasting. On the other hand we must not forget that agricultural produce is used for animal and human nutrition, and in this respect also these elements play a very important part. Equally it is the task of the fertiliser manufacturer to consider the question, and above all to examine these elements from the point of view of the law of diminishing returns as in the case of nitrogen, phosphoric acid and potassium. These products must not only be observed from the qualitative point of view but also it is necessary to know the quantity which must be applied to the soil.

Until now, the current methods of analysing fertilisers and soils did not enable this quantity to be determined, and although research and the application of analytical methods for these products are particularly expensive and complicated, it will soon be necessary to bear them in mind. In regard to animal nutrition, it is evident that fodder must provide the animal with these elements and in the cases where there is a deficiency, it must be supplemented by mineral salts but this is not really a remedy for this absence of elements.

I have divided my report into two parts: the first part is of a general nature and the second describes more particularly the experiments which have been conducted on this subject. I have divided the first part into three sections. Firstly, the technical aspect - influence of these elements on the yield of crops, on animal and human nutrition, and the influence on the price of fertilisers when these elements are added. The second section is mainly concerned with the chemical industry which is more in Mr. Fleury's line, as it is about methods and the profits of this production. Finally, the third section is purely of commercial interest - selling prices and propaganda for these new products. The second part of my report will deal with experiments which I have carried out on the subject of trace elements which partly provide a reply to the question put by Mr. Fleury on the increased prices which farmers would have to pay for products including these elements. I have divided the different mineral elements which should be used into four categories as shown in the Table below:

<u>A</u>	N, P, K
<u>B</u>	Ca, Mg, Na, S
<u>C</u>	I, B, Zn, Cu, Mn, Fe, Co, Mo, etc.
<u>D</u>	P, As, Se, Al, Ni, Cr.

In Group A are the principal elements, nitrogen, phosphorus and potassium which, until now, were the only elements which have been fully considered by the manufacturer. In Group B are calcium, magnesium, sodium and sulphur, which cannot be considered as trace elements for they occur in very large quantities in the soil. Group C contains the actual trace elements, iodine, boron, zinc, copper, manganese, iron, cobalt and molybdenum which are indispensable in the nutrition of plants. In Group D are given those elements which are not indispensable to the nutrition of plants and which are even toxic to them: fluorine, nickel, aluminium and chromium. I would again emphasize the distinction between the two groups containing the trace elements and the macro-elements N, P and K and I will give some information on practical results. I have not time to give you all the experimental results which I have obtained in my tests with cobalt, boron and molybdenum, all of which are contained in superphosphate. I shall simply quote the example of cobalt and show that with very small quantities of these elements I obtained most significant results, especially in the nutrition of cattle.

I have already said that cobalt is not necessary in the nutrition of plants but it is necessary for animals. All the same I think that animals should be given fodder of the best possible quality. In the experiments to which I refer, I analysed the roots and leaves of mangolds grown on plots receiving no cobalt and on plots receiving 250 gr/ha of cobalt sulphate. In the Table you will see on the left the quantity of cobalt in mg per kg of soil and on the right the results of the analysis of the roots and leaves. You will see very clearly the influence of the addition of cobalt in this experiment.

	mg/kg		
SOIL	Roots	Leaves	
I :	0.08	0.13	0.18
II:	0.15	0.37	0.36

In the feeding of dairy cattle it is necessary to provide 10 mg of cobalt per day which amounts to 3 gr per year per cow but, if you only give a ration of one gr. per year, milk production will fall to practically nothing.

With regard to profit, given that 100 kg of sulphate of cobalt costs something in the order of 60,000 frs. an application of 250 gr/ha, which would be sufficient in most cases, means that there is only an expenditure of 150 frs. per ha. Assuming that the cobalt contained in superphosphate is in the region of 0.2 gr per 100 kg of superphosphate it could all the same contribute to making up the deficiency.

I think, therefore, that although these quantities are small, in the future, agronomists as well as fertilizer manufacturers will have to consider the matter very closely.

I should now like to comment very briefly on the four reports which deal with this question. In the first report I do not agree with the graphs presented on Page 2 where it refers to the opinion of Mr. Barbier because I think that superphosphate contains very much higher quantities of sulphur than does the basic slag which is applied to the soil. On the other hand, there are the reports of Mr. Larsen and Prof. Fruhstorfer on manganese and I should be pleased if they would discuss the reasons why the addition of manganese to superphosphate maintains this element in a soluble form.

THE CHAIRMAN: I should like to thank Mr. Poll for his remarks, and suggest that we now pass on to the discussion of the papers.

As the paper by Messrs. Charliers and Carpentier is of a general nature, I propose that we open the discussion on the paper by Prof. Fruhstorfer.

Mr. N. CHARLIERS (Belgium)(Interpretation): I should like to reply to Mr. Poll's most relevant observation. The work done by Mr. Carpentier and myself presents compilation and does not report research. On the other hand, I think that Mr. Barbier has insisted on the fact that there is no luxury consumption of sulphur, but I think that when sulphur is added to the soil the sulphur content of the soil is increased, but the consumption by the plant remains at a certain level and never exceeds it. Therefore if there is a certain deficiency of sulphur in the soil and basic slag is applied, it is obvious that if we add superphosphate as well we would have a higher content of sulphur in the plant. The conclusion is that the sulphur is useful and quantities sufficient to act as a reserve should be applied.

PAPER NO. PA/148 - INFLUENCE OF SULPHUR CONTAINED IN SUPERPHOSPHATE ON PLANT GROWTH by Prof. A. Fruhstorfer.

THE CHAIRMAN Have you any questions to ask Professor Fruhstorfer on paper PA/148 "Influence of Sulphur Contained in Superphosphate on Plant Growth?"

PROFESSOR A. FRUHSTORFER (Germany): Mr. Chairman, I have brought some slides and I would ask your permission to show them. First I should like to make a few remarks on these experiments. We took a soil from our neighbourhood, and we used the soil which was most deficient in sulphur, the content of sulphur being 0.028 per cent. Firstly, in 1954, we took three crops without experiment, and then in 1955 we carried out experiments with sulphur. We did not expect any success because we were of the opinion that our soils contained enough sulphur for plant growth.

Then we got a surprise. This slide shows the first experiment, the first pot containing nitrogen and potash: 1 g. of nitrogen per pot and 1.2 g potash per pot. The second pot has the same amount, - 1 g. of nitrogen per pot and 1.2 g. of potash and no phosphoric acid and no sulphur. There is the same amount of nitrogen and potash and gypsum corresponding to the content of superphosphate on the basis of 0.3 g. per pot.

The third pot has the same nitrogen and potash as the first one plus superphosphate 0.3 g. of P₂O₅. The fourth pot contains fertiliser nitrogen and potash plus the same salts which are in superphosphate, but without sulphur, without gypsum. The last pot contains the same fertiliser as the fourth, but there was also salts with gypsum.

The second slide shows the next experiment on the same soil, the same fertilisers. You see that the deficiency in the soil has been increased by this experiment.

The third slide shows the experiment pretty late in the autumn with the same fertilisers. The fourth slide was taken this year when we took another sample of soil and we did not mind about the content of sulphur. The content of sulphur was higher - about 0.4 per cent - and we only used this soil for one crop. We then carried out the experiment again with mustard.

The fertiliser is the same: in the first pot without potash and sulphur; in the next pot with nitrogen, potash and gypsum; in

the third pot with nitrogen, potash, and super; in the fourth pot with the pure phosphate salts but no gypsum; and in the fifth pot with pure salts and gypsum.

The fifth slide shows the same experiment later on. This was in the spring and a few weeks later when the mustard was nearly ripe.

We did not expect this success and we are now of the opinion that in Germany we have millions of hectares of sandy soils with the properties which I have shown. Therefore, it is our opinion that we are nearing the time of onset of deficiency. If our methods of fertilising do change in future, and if we do go over to concentrated fertilisers, or complex fertilisers, then I think the danger of deficiency of sulphur is very near.

MR. D.J. BIRD (United Kingdom) Gentlemen, I should like to suggest that for the remainder of this discussion we try and discuss, between the agronomist and the technician, how we are to meet this new situation. We all realise the importance of these trace elements and, on the commercial side, the farmers and the salesmen are demanding more and more concentrated fertilisers which the technicians have got to produce, but how are we to bridge this gap between the more concentrated fertilisers and the need for trace elements? Should they be added to the concentrated fertilisers? If so, how much and in what form? Or should they be applied separately to the soil, or in the form of liquids as foliar nutrients? Perhaps we could try to confine the rest of the session to discussing that aspect of the problem.

(Mr. D.J. Bird - in the chair)

THE CHAIRMAN: I have been asked by Mr. Dior to ask you to excuse him, and he has asked me to preside over the remainder of this discussion.

As I said before, I think we are all conscious of the importance of trace elements: the problem facing industry is how to tackle the lack of these elements in view of the growing tendency of more concentrated fertilisers.

Would anybody like to speak from the production side. Dr. Scheel?

DR. K.C. SCHEEL (Germany) (Interpretation): As far as the manufacturers are concerned, they are perfectly capable of putting any of the trace elements and materials into the fertiliser if required; there is no difficulty in that direction. But is it not dangerous if these fertiliser manufacturers just add all the various trace elements to the fertiliser?

MR. N. CHARLIERS (Belgium) (Interpretation): I want to stress the point that one must before all avoid any confusion between the secondary major elements; for example, calcium, sodium, magnesium and, of course, sulphur, and the true minor trace elements which have been enumerated this morning. These two groups must be clearly separated in the problem we are discussing today. This is most important and all the trouble starts here. The fertiliser industry itself is progressing towards the manufacture of so-called more and more concentrated fertilisers, but this is really only a trap, since it is just the three classical elements which have such a high concentration, namely N, P and K. This does not mean, however, that the fertilisers are concentrated.

Concerning trace elements there is no question of concentration. It is no longer a problem of concentration which the manufacturer has to face, for the addition of "traces" of copper, molybdenum, zinc, etc. to fertilisers, because they are necessary from the agronomic point of view, is a question which, in regard to the concentration of the final fertiliser, is not of any importance. Thus, if we are anxious to make fertilisers very rich in N, P and K - as Mr. Fleury

said this morning - it is simply because authorities do not allow the manufacturers to put any value on the sulphur in the fertiliser. Of course, since we can put no value on this element, we might eliminate it and reduce transport costs of one element.

I think this is an important point, for we can look at it this way, there are two things to be done - let elements other than N, P and K remain, and add traces of minor elements as medicine if the agronomists think it necessary.

MR. I.A. BROWLIE (United Kingdom): Mr. Chairman, from the manufacturing point of view, the subject of the addition of trace elements to fertilisers has perhaps the difficulty of diversity of soils and the diversity of fertiliser compositions which might be required. I wonder whether the manufacturers could possibly produce a large range of fertilisers with different amounts of trace elements. Obviously it would be uneconomical to produce the various tonnages required for each individual type of soil. Perhaps it will in the long run be possible to standardise the type of trace element addition required.

Another alternative that I can foresee is that it may be possible to add the trace elements in the form of liquid fertiliser solutions which could be applied in two ways, either as a foliar application or an application to the soil in the normal way.

There is just one other point on the subject of determination of trace elements in the soils. I wonder whether the Lundegarth flame spectrographic method might be suitable for determining the constituents of the soil?

MR. SOUBIES (France) (Interpretation): I agreed with the distinction made by Mr. Charliers with regard to the secondary major elements and trace elements, but after the discussion I realise that the main problem is the problem of sulphur, for the other elements are contained in rock phosphate and they are applied to the soil whether they come from superphosphate or from any other form of phosphatic fertiliser made from rock phosphate.

But with regard to sulphur, the question which manufacturers ask is "should we continue to make traditional fertilisers, or must we manufacture more concentrated fertilisers?" As the result of legislation, we find ourselves making more and more concentrated fertilisers which contain less and less sulphur. At the moment, the agronomists are no more than worried about this. They say that there is a danger if sulphur is not included, but they are incapable of pointing out - forgive me for saying so - that the absence of sulphur will lead to a very important decrease in yields or to very serious results in certain cases, and these agronomists are no more dependant on manufacturers than are the official agronomists. I think there is a lack, not of sulphur, but of agronomists.

That is why I propose that the farmers pay for the sulphur we are giving them and this is a question which must concern the manufacturers, who do not want to add this element. If it would serve any purpose, we must demonstrate to the farmers that it is in their interests to apply sulphur, and consequently the benefits and advantages of using sulphur must be shown by careful experiments. It seems to me that we cannot reply at the moment to the question put by the manufacturers, but that we ought to be able to answer them shortly, if we make a concerted effort in all countries to carry out comprehensive trials.

MR. B. RAISERICK (United Kingdom): Mr. Chairman, I have been a little bit disturbed at the way the discussion has gone this

morning. I should like to say a few words to the agronomists as a technician. Nitrogen, phosphorus and potassium are the main plant foods with which the manufacturer is concerned. They are the main plant foods, I think, because most crops, most soils, need them. Some other materials are essential for some crops: there is boron, for example, but boron will never be a major plant food, I imagine, because, although it is necessary for one particular crop, say, roots on one particular soil, the quantity that one uses might cause damage to other crops. So the manufacturers do concentrate on N, P and K, and their aim has been, and still is I think, to give N, P and K to the farmer at the lowest price. Nowadays there is an additional factor beyond that of the lowest possible price, and that is the most concentrated form so that the farmer can handle these things with the minimum of labour. Unless there is a change of heart and unless there is new information coming forward from the agronomists, I believe that this move towards more concentrated fertilisers containing N, P and K will continue.

Therefore, I was unhappy this morning when speakers spoke of incorporating trace elements in fertilisers. In my opinion, one should think of incorporating trace elements in soil. The easiest way to put them into the soil might be by way of the fertiliser, but that will not always be so. One speaker this morning - I think it was Mr. Poll - pointed out the quantity of cobalt was very small and, therefore, it cost very little, but as a manufacturer might I put this point to him? It is true that the quantity of cobalt is small, but let us see what happens if the manufacturer puts cobalt into one fertiliser, puts boron into another, magnesium into another: he ends up with having to manufacture large numbers of fertilisers. In some countries fertilisers are manufactured over most of the year and are stored to be sold in the spring. So let us consider what would be the fertiliser manufacturer's position if he had to incorporate large numbers of trace elements in fertilisers.

I will illustrate this by speaking of a company in the United Kingdom: a company in the United Kingdom might have, say, four fertilisers on its range, on its catalogue. If we start putting cobalt, boron and sulphur specially into those fertilisers, the same manufacturer might have to manufacture twenty fertilisers.

If he is to meet the heavy demands in the spring and needs twenty fertilisers, his stocks at the start of the sowing season will have to be very much larger in the case of twenty fertilisers than in the case of four. Therefore, there will be extra expense there.

Secondly, there will have to be extra expense in storage to store twenty fertilisers instead of four. Different labelled bags will probably have to be kept for each of these twenty fertilisers; special techniques of handling will have to be developed to make sure that some of the fertilisers containing toxic trace elements do not get mixed with other fertilisers, because as I said, boron, for example, is dangerous to other crops.

I can assure agronomists that when they are thinking of the cost of a trace element, they must not think merely of the cost of the little bit of cobalt, or the little bit of this, that and the other which goes into the fertiliser. It will cost more than the cost of the element alone.

However, fertiliser manufacturers will undoubtedly supply any trace elements that are needed: their livelihood depends upon it, but in the case of each trace element there will be the most economic way of doing it. Occasionally this might be to put the

trace element into the fertiliser, but in my opinion more often it will be to fertilise the land with an N, P and K fertiliser and to treat any particular deficiency with the element concerned separately when the deficiency has been identified. In my opinion, the shotgun approach of incorporating trace elements is likely to be wasteful and dangerous. That is why I am not very happy about the shotgun approach of using the trace elements in superphosphate. It is true that there are trace elements in ordinary superphosphate which come from the rock and the acid, but would it not be a coincidence if the quantity of those trace elements in superphosphate happened to meet the demands of the soil?

Therefore, I feel that every trace element deficiency will have to be dealt with in its own right rather than by a shotgun approach. I do suggest that the most economic way of doing it will by no means always be to put the trace element into the fertiliser.

MR. N. RICHARD (France)(Interpretation): With regard to the problem of sulphur and superphosphate which Mr. Soubiès mentioned, there is evidence in the literature that the continued application of triple-superphosphate, which contains no sulphur, to the soil decreases the yields as compared with the application of ordinary superphosphate. This has been mainly shown in the United States where some companies had to sell gypsum with concentrated superphosphate in order to meet the deficiency.

In France we carried out several six-year experiments in Brittany and the plots where triple-superphosphate was used gave lower yields of potatoes than those with ordinary superphosphate. But returning to the ideas expressed by Mr. Soubiès: the question of sulphur in superphosphate is very important; would it not also be important for propaganda purposes, even if we are not authorised to put any value on the sulphur? If you like, a proportion of the high price per unit of P_2O_5 might be charged on part of the sulphur content, and I think that since these experiments are easy, they could be carried out in many West European countries. However, we must allow about four consecutive years for these tests and then draw up a common policy on this important subject.

MR. A. DAUJAT (France)(Interpretation): There is one danger which arises from the fact that if you apply more concentrated fertilisers, they are more readily washed out, and that applies in particular to sandy soils such as are found in Brittany. I quite agree that on the whole phosphoric acid is stable, but in the case of sandy soils there is the possibility of it being leached out if it is applied in the concentrated form. There again I stress that ordinary superphosphate actually scores inasmuch as it causes a certain amount of fixation and thereby counteracts the possibility of washing out.

With reference to trace elements, on the whole there is a very slight lack of trace elements in France. There are some deficiencies such as manganese in Brittany, copper in Landes, boron for sugar beet in the Paris and Seissons regions, and on the river Loire there occurs a certain amount of magnesium deficiency.

I am of the opinion, therefore, that in order to fight against trace element deficiencies, there are other possibilities than to incorporate them in fertilisers. But we can use magnesium salts and some nitrate of lime with magnesium is being manufactured in France.

With regard to trace elements or minor elements themselves, it may be dangerous to make such products available to farmers because the accumulation of those products in the soil always proves toxic in the long run. For instance, in France there are regions where

they use a lot of borax in order to fight against heart-rot disease: this borax remains in the soil and after 7 or 8 rotations it becomes toxic for cereals. Therefore I do not think one should mix the propoganda for trace elements with that for nitrogen, phosphorus and potassium, which is the main thing to deal with in order to avoid giving too much importance to those trace elements as compared with the main elements.

I should also like to stress that some of the deficiency cases which do occur are due to over-liming. For instance, over-liming in Brittany led to deficiencies of manganese and boron. When the lime, after three years, became washed out, the deficiency in manganese disappeared without any additional application of this element.

MR. A.I. COLLEMAN (United Kingdom): Mr. Chairman, if I understood you correctly, the indication you gave us at the opening of the discussion was that you felt we should concern ourselves in the main with considering whether, in view of the increasing tendency to use concentrated fertilisers, we should take any steps to take into account the trace element position. In other words, is it a good thing to go for concentration if, in so doing, we are doing the wrong thing in regard to minor elements in the soil. We have had difficulties associated with production, we have received warnings concerning the publicity side of their industry in regard to customers, and with all these I do associate myself wholeheartedly. But I suggest that this is really a problem concerned with the sustenance of life. We do not give the nation a tonic because in four years' time it may become run down. The problem is one which I feel should be regarded statistically and assessed in perspective.

On the side of the production people, I should say we are very interested to hear about these trace elements; we should like to know whether every field in the country is concerned in this matter today, or whether only one per cent of the fields is concerned. I agree with the view which has already been expressed, that trace deficiencies are likely to be of local importance only. I suggest, therefore, if that view is the correct one, the position of the agronomists in the future is a lot more important than perhaps we appreciate today. They will be regarded as the doctors who are called in to diagnose the position. They will presumably have the task of telling us on the production side what the field requires, and we shall say whether it is going to be economical to incorporate this material into fertilisers or to be applied separately.

I would suggest that the position which may arise in the future is that we could go ahead with confidence in producing more concentrated fertilisers and that, out of every thousand tons of concentrated fertiliser we produce, only one ton will come up for consideration as to whether it should have incorporated with it one or more trace elements.

Speaking again from the production point of view, I express my concern in connection with some of the evidence which the agronomists place before us. At an earlier session we were considering the effect of particle size upon agronomic efficiency. One author said there is a pronounced effect especially in the early stage of life, and that effect was sufficient in the circumstances he described to produce a noticeable effect in regard to the yield of plant.

Another author, reviewing the position arising from a great deal of published matter, said he could not find any considerable evidence either in favour of granulation or against it. There are some differences of view here, and it seems to me possible that such differences may be concerned entirely with the differences of

trace elements that were present in the soil when these authors were making their investigations. We have already received very interesting evidence concerning the effect of these minor and macro-elements on the effect of plant life, but I suggest that such differences as we have already seen might very well not be capable of duplication were the same experiments to be carried out in another country where there is a difference of one part per million in regard to the plutonium content of the soil. It is difficult to understand whether the evidence is of a national, international or acreage significance.

MR. L. DIDIER (North Africa)(Interpretation): I should just like to give you an example of the local character of the lack of trace-elements. There were two farms in the Black Forest which were next-door to each other, on one farm there was a lack of cobalt whilst on the other farm there was none. As far as the cows were concerned, there was definitely disease among the cows which were grazing on the pastures on the farm with a lack of cobalt, and eventually this even led to some of the cows dying. Research was carried out and it was found that there was a geological fault between the two farms and that the soils were different, in one of them there was a complete lack of cobalt. It was sufficient to put cobalt salts in the drinking-troughs to eliminate the ill health caused by the deficiency. Thus, it is usually very local; sometimes it is extremely localised.

DR. R. STEWART (United Kingdom): As an agronomist, I wanted the chance to reply as generally as possible to Dr. Raistrick. If I understood his remarks correctly, he tended to suggest that it was the agronomist who was anxious to see the manufacturer make a large range of compounds. I should like to suggest that that is not the case. He went on in his own remarks to make that admission himself. I could not agree with him more when he said that deficiencies of trace elements as they occur in practice must be considered on their own merits and case by case. It is true that there are very considerable areas in different countries throughout the world, particularly in Australia, South Africa and some parts of America, where there is a fairly general and widespread deficiency. Many hundreds of thousands of tons of molybdenumised superphosphate have been manufactured and consumed in Australia and very large tonnages of cobaltised superphosphate also. But with the exception of these definite areas, in most other countries deficiencies of trace elements occur somewhat sporadically and although they may be of very serious economic importance to an individual farmer, they do not always affect a very large area. I do not think we can reach any general conclusion at this meeting as to what manufacturers in all countries should be doing. I think the position will be that in each country the need for a particular element will have to be demonstrated; the quantity required to correct a deficiency will have to be determined by field experiment, and the most economic way of applying that amount will have to be found.

MR. A. KAMEL (Israel): I should like to support the view expressed by Dr. Raistrick and other speakers here by an example from my country. A considerable part of the irrigation water is dangerously rich in salt and, as everyone knows, this may cause the physical deterioration of the soil. A well-known and very efficient method to correct this is by adding calcium in the form of gypsum to the irrigation water.

Now we are trying to pass on from single superphosphate to triple-superphosphate manufacture. Some sceptic people put the question, "Why go to the trouble of making phosphoric acid for triple-superphosphate manufacture if we have to put the same gypsum back in the irrigation water to overcome the dangers of the

application of salty water?" Quantitative analysis of the problem has shown that it is not so. For those areas and those fields in which the application of gypsum is needed, the gypsum contained in the superphosphate will be by far insufficient. On the other hand, if it were added in other areas where there is no need for gypsum, the gypsum accompanying the single superphosphate would be superfluous. So it is a very reasonable tendency to separate the gypsum from the mono-calcium phosphate and to apply it where it is very necessary, and to apply the concentrated form where there is no need to add gypsum. I am speaking from the point of view of calcium, not from the point of view of sulphur which is now under investigation in my country. On the whole, I think the trend of going to purer and more concentrated forms of fertiliser is a very healthy one.

MR. P. FLEURY (France)(Interpretation): I am in complete agreement with Mr. Daujat who has placed us on our guard against the error of taking secondary elements as essential and of advertising fertilisers containing trace elements too widely, for there is a risk of supplying excessive quantities to inexperienced farmers. But on the other hand we are told that there is a lack of trace elements. These deficiencies appear only when the crops are harvested, and it is hardly possible to detect this deficiency before the amount of trace elements in the soil has been considerably reduced. But, as for N, P and K, one would think that there could be an appreciable influence on the yields, as soon as there is a decrease in the content of trace elements below a certain level, and at the present time I think that it would be particularly impossible to detect a decrease of the order of 10% to 15% of yield due to this deficiency because there are too many other factors concerned.

The importance which this decrease of 10% to 15% assumes for a large number of farmers justifies comprehensive research being carried out to discover when the actual deficiency begins as shown by the commencement of decreasing yields rather than a very poor one.

MR. GISIGER (Switzerland)(Interpretation): I am very interested in Mr. Daujat's remarks and also those of Mr. Charliers. As far as Switzerland is concerned, I am in full agreement with what these gentlemen have been saying.

There is also a danger of misleading propaganda in regard to the minor or trace elements. After consideration, I do not think the statements by Dr. Radstrick and by Dr. Stewart are in opposition. As Dr. Stewart himself said, very often the lack of trace elements is only spread over an area of several square metres.

I am also in agreement with the statement that one has to be very careful about the application of the minor elements and the danger which may be brought about by an excessive application of these minor elements. I would, for example, refer to the case of over-liming which sometimes results in too great a fixation of manganese.

With regard to Switzerland the main propaganda is for the application of boron in conjunction with compound fertilisers, but even then they are very careful and only advise an application of four per cent in the fertiliser for fields and two per cent for garden crops.

The position of sulphur is in the process of being studied internationally, and there is an association in being, led by Sweden, which wants to devote its studies very intimately to the question of sulphur.

Apart from boron, there is also the question of sulphur in those countries which are near the sea. There is no doubt that, through the modern industrial development, very important quantities of sulphur are produced by coal burning and oil burning and are then, of course, consequently found in the air. In Switzerland the quantity of sulphur obtained by that means amounts to 30,000 tons, but unfortunately these quantities are not regularly dispersed. Formerly it was very necessary to fertilise with gypsum, but nowadays, with the amount of sulphur which is available from the air, this need is to a certain extent reduced.

MR. K.A. SHERWIN (United Kingdom): The economic production of fertilisers depends on manufacturing in vast tonnages as few types as possible and providing enormous storerooms to house the material in the off-season. The trend towards more concentrated fertilisers is continuing very fast, and I suggest that if the secondary elements - that is, those like sulphur, calcium, etc. - which will tend to prevent the achievement of highly concentrated fertilisers, are to be of importance, the most important question to be resolved by the agronomist is this particular one: the present impulse towards more concentration is not one that can be easily reversed later on.

MR. D.E. SIMPSON (United Kingdom): I should like to express my support for what Dr. Raistrick has said, and also Dr. Stewart, mainly because any form of grape-shot treatment is utterly and completely unscientific. I would add two points to what Dr. Raistrick has said which I do not think anybody has mentioned.

Very often one farmer will put on twice as much of one fertiliser as another. Accordingly, what is right for one must be wrong for the other, if you are dealing with fine limits. Again, that fertiliser may be placed or broadcast and what would be perfectly safe to broadcast would not be perfectly safe if placed near the crop. The problem is really one for agronomists because I am quite satisfied that it will be quite simple to devise means of applying any kind of minor element or secondary element where it is needed.

I said that it was unscientific because the grape-shot method does not take into consideration the interactions which sometimes take place between these elements, and does not take into account the economy. The simplest form, of course, of interaction between elements is that between calcium and manganese. Manganese is really deficient because there is too much calcium in the soil, either because the soil is naturally calcareous or because too much lime has been applied. If the soil is not naturally calcareous, that can be taken care of by seeing that over-liming does not take place.

From the point of view of the agronomist, it is not all that easy either, because soil analysis may be difficult. Just as in the case of P_2O_5 , you have got to determine what amount is available to the plant. Tissue analysis may help, but even then I am not sure if we know what the normal amount of any element is for any particular plant which is healthy. We have seen that potash can be absorbed in luxury quantities, so what is the normal amount of potash for a healthy plant?

Therefore, soil analyses or tissue analyses have got to be backed up by field experiments, as Dr. Stewart has said. We have got to find out what is to be applied, where it is to be applied, and I do not think we shall have any difficulty in finding out how it should be applied.

THE CHAIRMAN: I should like to ask Mr. Shantz whether he would give us any comments on this problem in Canada.

MR. K.A. SHANTZ (Canada): I can only say that this problem is quite common to us, and we are concerned with the question of concentration of fertilisers. This problem is being considered. In my own company we have taken one step in that we have been promoting trace elements through a sintered glass-type of material as a product in itself and with fertilisers. It is a rather expensive form of material, but it is quite effective and long-lasting.

I think I might say something with respect to the secondary elements in that I am quite glad to find that one of the papers and the discussions here today mentioned the value obtained from sulphur, in particular, going into the air from various other industries. We have that very much in North America, and particularly in my own country, where one smelter is putting out as much as 4,000 tons of sulphur per day into the air. We often wonder where it goes; somebody can maybe tell us. In other words, I think we are getting it back.

I think that is all I can add at the moment. If there is anything else, I will mention it.

MR. K. VOLL (Holland): From the practical point of view, before the war I made some mixtures with superphosphate, boron, manganese, etc. and the technical people were crying out that they had so many other things than just superphosphate. Since the war, we have had many grades of mixed fertilisers and so the total number of fertilisers was enormous. After that I got N, P and K and trace elements, and I now make a mixture of manganese sulphate and the different trace elements. I believe that is the best way, especially in the case of mixed fertilisers. If you have a number of grades, it is not necessary to have a big bulk of different mixtures of N, P and K, but only a small space for trace elements and manganese sulphate. I think in this way it is not more complicated but very simple.

MR. M.H. CLARK (South Africa): Mr. Chairman, I have no question to ask, but I have a suggestion to put to our agronomic confrères, that they attempt to assist the application of minor trace elements, in the form of organic materials rather than in the soluble mineral source which has apparently been tried. The reason for the suggestion is that, although I deplore the shot-gun method of approach, we may be forced, as manufacturers, to make mineral fertilisers with standard amounts of trace elements in them, and if they can be added in a form, from which the plant will take up only what it needs, as it might do from organic materials, then I think we should do that.

THE CHAIRMAN: Gentlemen, I think we have covered as much ground as time will permit. I should like, on your behalf, to thank the two introducers, the writers of the papers and the participants in the discussion. Being neither an agronomist nor a technician, my summing up of what we have discussed this morning is, first of all, that I think we have got to face up to the fact that higher concentration of fertilisers is inevitable. Secondly, secondary and minor trace elements are both important but must be kept in their proper perspective; thirdly, that both the agronomist and the technician must work together on this very important aspect of our industry and find the proper solution under their own conditions, bearing in mind the very important economic factor.

I will now ask Mr. Grandgeorge, who is unfortunately not able to be with us for this afternoon's session, to say a few words.

Mr. R. GRANDGLORGE President (France): (Interpretation) I should like you to excuse me for not being as diligent as I should have liked, but I know that Mr. Bird has taken the chair in a very competent way, and in the name of Council of the I.S.M.A. I should like to thank him most warmly for his assistance in the meetings and the discussions. He has told me that his task has greatly interested him. I should like to thank you all for the contributions which you have made, and for the support of the firms you represent. To my mind, this shows that economic co-operation between manufacturers is so important and so necessary to the age in which we live, where science and technology certainly help to give understanding and mutual comprehension.

As I shall not be present at the session this afternoon, I should like to thank our two secretaries for their work and to congratulate them on their task which cannot have been easy on account of the scientific nature of the language used.

In the name of the Association I should like to thank all those who have honoured us with their presence and in particular our Swiss friends who have received us so kindly during these three days, especially MM. Arnold, Gallay, Bourqui, Gisiger and Paccolat. I should like to express our gratitude to them for the very pleasant visits which we made yesterday, and for the interest which they have shown in our work.

Gallay,

This session will most certainly be recorded in the annals of our Association as a very vivid memory, for I think that the papers have shown how successful and interesting these meetings between agronomists and technicians have been in considering the new problems which arise from modern working methods.

In the name of the Association I thank you all very much for all that you have done here and for your contributions.

THE CHAIRMAN: I will now adjourn the Conference until 2 p.m.

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JOINT TECHNICAL-AGRONOMIC CONFERENCE

LAUSANNE: 24th-26th September, 1956.

Report of Discussions

Afternoon Session 26th September, 1956.

In the Chair: Mr. N. Charliers (Belgium)

Mr. D.J. BIRD (United Kingdom): Gentlemen, we now come to the Fourth Session, "The Possibility of developing rapid tests for new fertilisers". This is a subject which has been discussed on a number of occasions and there is a divergence of view between the technicians and the agronomists. The technicians say, "Here we have a new product. We want to invest large sums of money to make it. Before we spend the money, is it a good fertiliser?" The agronomists say, "It would take us three or four years before we could tell you whether it is a good fertiliser or not". And the technicians say, "In view of the competition from other firms, we can't wait for three or four years: we must have a quick answer".

The problem for discussion this afternoon is whether there is a quick and accurate method of determining whether a new product is a commercial risk that is worth taking or not.

Now, Gentlemen, I am going to ask Mr. Charliers, the Chairman of the Agronomic Advisory Commission, to take the Chair during this Session. When we have finished this Session, I am going to ask Mr. Charliers to sum up very briefly from the point of view of the agronomists, and Dr. Scheel to sum up from the point of view of the technicians.

THE CHAIRMAN (Interpretation): I thank you for the honour of being given the Chairmanship of the last Session of these meetings.

Our first paper this afternoon is by Dr. Raistrick and Mr. Rickson; the next paper is by Dr. Scheel, and the last paper is by Mr. Talmi and his collaborators. The first paper to be discussed is PA/145, but before we begin that I would call upon Dr. Thiessenhusen to introduce the subject.

DR. W. THIESSENHUSEN (Germany)(Interpretation): I have great pleasure in following the advice of Mr. Bird. He has decided to be as brief as possible in order to allow a more lengthy discussion. I would particularly stress the necessity of having a rapid method for determination so that advice can also be given from the agricultural side within a very short time.

I would say that somehow the three papers and the subjects treated do not quite fit in together. All three deal with rapid methods, but if they were to include, in addition to the new fertilisers, those fertilisers which are already known, then the subject to be discussed in the three papers would fit in together.

The paper by Dr. Raistrick deals with the chemical means of determining the nutritive value of fertilisers for plants. This then is the actual evaluation if these methods have to be left to the agricultural chemist and also to farmers, to find out how far this method actually does apply.

Secondly, there is the paper by Dr. Scheel which, I think, speaks for itself.

Thirdly, there is the paper by Mr. Talmi and his collaborators. This paper refers in the main to a production question. It would, of course, be a very great help to the manufacturers if they could, by applying this method, save themselves a tremendous amount of time, labour, and also a certain amount of annoyance.

In conclusion, it is very necessary to continue with our endeavours to find more rapid methods, not only in regard to the usefulness of the fertilisers, but also in regard to the micro-element contents. To my mind, it should also be the future endeavour of the chemist to develop still more and more rapid methods as the time goes on.

THE CHAIRMAN (Interpretation): Professor Fruhstorfer will introduce the discussion from the agronomic point of view.

PROFESSOR A. FRUHSTORFER (Germany): The subject of Section 4 is "The possibility of developing rapid tests for new Fertilisers". Therefore, we have to deal with new fertilisers with unknown properties and, from the standpoint of the agronomist, with soil, because we are convinced that we can discover the properties of an unknown fertiliser only by testing them in soil. From this point of view, the paper of Dr. Scheel does not belong to this Section, as Dr. Thiessenhusen has already mentioned: it belongs to Section 1. His paper deals with potash, which is a known fertiliser, and he wants to determine rapidly the potash content in fertilisers. Indeed, it is a marvellous method for the rapid determination of potash in the works, and the analysis is made without skilled personnel, without balances, without chemicals, even without water; nevertheless, the analysis is exact by weight.

Now referring to the remarks of the Chairman, we agronomists do not object to rapid tests: we use rapid tests in soil analysis. As a matter of fact, we use the soil analysis instead of long field experiments. These rapid tests in soil analysis have been developed for fifty years: just as long as the age of our agricultural chemistry. In spite of this fact, we know that the use of fertilisers mostly takes place without knowing the content of the soil. Since the deficiencies of macro-elements do not show significantly in the plants as a rule, it is the opinion of many agronomists that the waste of nutrients - especially when we use complex fertilisers - is far larger than the waste of minor elements, because when we use minor elements, such as boron, manganese or copper, we have significant symptoms on the plants. The plants are not healthy; we must cure the plants by the use of trace elements.

However, we do not know the deficiency of the soil or plants with the macro-elements. Rapid tests are nowadays developed for the minor elements as the research-workers are still working on the improvement of soil analysis in general. So rapid tests for new fertilisers are necessary in order to save time and to avoid errors which are pretty often given in field trials.

Now a very good addition to Section 4 is in Section 1, the paper of Dr. Scheel, "Quantitative Determination by means of P^{32} of the Absorption of P_2O_5 by Living Plants". Unfortunately there was no discussion on this paper, and I should therefore like to draw your

attention to it. It deals with the up-take of phosphorus out of every fertiliser. It deals with every phosphatic fertiliser which can be tagged, because not all phosphatic fertilisers can be tagged. So we are able to find the exact up-take in a few weeks, and I think the up-take is what we want to find out. As I mentioned we sometimes have errors in field experiments, but we can never have an error if we have the radio-activity of phosphorus measured in living plants. Therefore, this method of Dr. Scheel gives more than was to be expected. It can be used with every plant desired, with every method of application, and, as a matter of fact, it is a real attempt to find a rapid test for new fertilisers.

There is another paper in our programme, that of Dr. Raistrick and Mr. Rickson. This is a very good attempt to assess the value of phosphatic fertilisers in the laboratory. The value of a fertiliser can be determined quickly in the laboratory, and so I think it is a very good effort on the part of the research-workers. However, I can also foresee trouble. I stress that, in my opinion, soil and rapid tests in this case belong together. In this system the soil solution and the solid fertiliser are influenced by other things, for instance, either the CO₂ content, the acid secretions of roots, or - and this is something I want to stress above all - the fact that the soil is not a uniform mixture which can be shaken, but is a very beautiful mosaic of all possible particles with many different pH values and different redox potentials. There is, for instance, the influence of organic matter: organic matter is never uniformly distributed in the soil. You will find the organic matter always in the form of a pocket: organic matter in the soil influences the placing of this pocket and you can assume that the pH in this neighbourhood is lower; the CO₂ content, the concentration near the pocket is higher; also there may be nitrogen fixed in some of them.

You will appreciate that the rapid test should take into account all these asponderables. Also tests in the laboratory cannot replace the treatment with the soil. I am sure that the scientific work of Raistrick and Rickson is of the greatest value so far as a better assessment of our fertilisers is concerned.

That, Mr. Chairman, is what I want to say in opening the discussion.

PAPER NO. PA/146 - PLANT NUTRIENT VALUE OF FERTILISERS BASED ON CALCIUM PHOSPHATES - by B. Raistrick and J.B. Rickson (United Kingdom)

THE CHAIRMAN (Interpretation): Have you any questions on this first paper?

MR. A.I. COLEMAN (United Kingdom): Mr. Chairman, if I may, I would for a moment refer to Mr. Bird's questions concerning the need to have reassurance of the agronomic suitability of new chemicals. Such a reassurance is required by those who have to design the plants and invest the money necessary for their construction. I would say that, simplifying Professor Fruhstorfer's summary of the position, the answer is "No". I think life is far too complex to be settled by a simple test of duration of a few months.

I would like, if I may now, to refer to Dr. Raistrick's paper PA/146. Although it does not appear to be possible to devise rapid tests which are, in effect, agronomic appraisals, it is, of course, as Dr. Raistrick and Mr. Rickson have shown, possible to devise rapid methods to determine the rate at which fertiliser nutrients can become available in the soil for up-take by plants.

In the last paragraph of this paper, Dr. Raistrick and Mr. Rickson say that they recognise the controversial nature of the issues involved, and they hope it may stimulate a discussion. It is indeed a controversial matter. I think perhaps I should say that there are very few papers which become available to us dealing with the dynamic aspect of the rate at which fertilisers enter the soil. We have excellent papers - for example, Professor Fruhstorfer's - which analyse the rate of up-take; but there are very few on the rate of solution. With phosphate chemistry being as complex as it is, it has always been the *bête noire* of chemists and technicians from time immemorial. I feel we must all feel very grateful that we have available to us today such a paper by Dr. Raistrick, who is an acknowledged expert on the subject.

I think perhaps the most controversial word in Dr. Raistrick's report - it is probably one which he has included intentionally - is the word "value". The title of his paper is "Plant Nutrient Value of Fertilisers Based on Calcium Phosphates". At a later stage in his report there is a paragraph which mentions the scale of relative fertiliser values, and there are other sections which have such words as "values in calcareous soils". The values he is referring to are, firstly, the rate at which these materials enter the solution, and, secondly, the rate at which they can be taken up. These are not values at all, they are coefficients. One way in which the word "value" may be regarded by those who are perhaps not so well informed as Dr. Raistrick is that this is an effort to prove that mono-ammonium phosphate is a more valuable fertiliser than fertilisers based on calcium phosphate, and I hope he may be able to clarify his interpretation of the word "value".

DR. B. RAISTRICK (United Kingdom): I should like to comment on Professor Fruhstorfer's points first, if I may.

Professor Fruhstorfer makes the point, quite rightly, that our quick method does not use soil in it, and he then goes on to point out that it would be better if the soil could be used because when one starts to consider soil there are such factors as pH, carbonic acid content, composition of soil, organic matter in the soil, lack of uniformity of soil, the effect of root secretions on solubility of fertilisers. He points out that our technique does not take these into consideration. That is quite true, but the evolution of this method was difficult enough without taking all these other enormously complicating factors into consideration. It was difficult enough to do this exercise using pure water; to have done it under varying conditions, such as pH, the carbon dioxide content and so on, would have meant that it would have taken an enormous amount of time. In the present state of our knowledge, I do not think we can take these imponderables into account, and if we did the test which would come out it would not be very rapid. Maybe in ten years, twenty years, we shall be able to take some of these considerations into account, but at the moment I am pretty sure that we could not.

To comment on Professor Fruhstorfer's final point, the procedure given in this paper is not intended to replace field testing, of course. When new fertilisers are being developed, the number of possibilities in which one can engage for field testing are enormous, the work involved in testing every new fertiliser on different soils and different crops is enormous, very expensive and very time consuming. All we have hoped to do is to give a rough sieve which we believe will reduce the number of field tests which one has to do in the case of a new fertiliser to manageable proportions. We hope that by using a test of this kind, instead of having to do an enormous amount of work, one might divide it by a factor of ten or fifteen and bring it down to practicable proportions.

Perhaps I might now comment on Mr. Coleman's question. He says that in this paper we often use the word "value", and he is right. He says that coefficients might have been a better word, but in the fourth paragraph on page 1 of the paper I have tried to explain our terminology. The figures which we bring out I describe as relative potential values, and the use of the single word "values" after that time is just to have to avoid saying "relative potential" a few hundred times in the paper.

Finally, Mr. Coleman wonders if this paper is an effort to show that ammonium phosphate is the best phosphatic fertiliser. For those who do not know, I suspect that the significance behind that comment is that Mr. Coleman knows that my company have decided to start manufacturing ammonium phosphate, but the work in this paper was done several years ago; it was done in 1953/1954, before that decision was taken, and there is no roundabout propaganda going on. But I do believe, nevertheless, that our work shows, and a lot of agronomic work shows, that, taken over all, and taking a broad section of land and a broad section of crops, water soluble phosphates, of which ammonium phosphate is one, is a better source of phosphorus than are the basic calcium phosphates, such as dicalcium phosphate and hydroxyapatite. I do believe that.

THE CHAIRMAN. Thank you very much for these answers. I am very glad that Dr. Raistrick has given some details about the aim of his method, which is the "sieving" of the various products, which saves time and money for the industrialists; but in my opinion such methods cannot give more than they are capable of giving, but the fact that they have made economies possible, shows them to be worthwhile.

MR. M. SOUBIES (France) (Interpretation): I should like to make a few observations on Dr. Raistrick's method. Without any discussion with Dr. Raistrick, a few years ago I tried this method in my station at Toulouse to determine the value of the various dicalcium phosphates as contained in various nitro-phosphates and other insoluble phosphates such as basic slag and aluminium phosphate. I used tap-water with a pH of 7.2, and I made 36 water extractions in order to know the proportion of phosphoric acid which can be extracted by washing with water.

With this method we manage to get cumulative curves, showing the quantity of phosphoric acid recovered which can be taken up with a series of water extracts. With fused phosphate we found that 100% was washed out in 20 extractions. With the various nitro-phosphates which we tried - those nitro-phosphates which had given different results on crops - we expected to get different results with that method. But unfortunately this was not the case: after 20 extractions we arrived at an equilibrium of a rate of recovery of 65 per cent which we could not exceed.

With regard to phosphate rock or fused aluminium or calcium phosphate, the rate of recovery always remains very, very low, however many extractions are made. Therefore, taking those tests as a basis, you could say that the values of those different fertilisers are 100 for fused phosphate, 65 per cent for nitro-phosphates or basic slag and 5 for rock phosphate or for aluminium phosphate. The answer found by growing crops on calcareous soils is quite different from the answer given by that method: for those fused phosphates it is nearly 100 per cent value, the same as that of superphosphate. But for nitro-phosphates the range of values goes from 35 per cent to 100 per cent of the value of the super; that of basic slag compared quite favourably with superphosphate, that is 65 per cent on calcareous soil and for rock phosphate and aluminium phosphate applied to a calcareous soil the difference is much bigger than the one you can see from this test: for rock

phosphate it is nearly the same, but for aluminium phosphate you reach the same value as for basic slag.

In conclusion, therefore, I would say that I do not rely on this method of successive dilution. First of all, it is not a very rapid method because if you want to keep the pH to 7.2 you have got to wait for two months at least. Of course, the best method is by field experiments, but if you have no time to do that, you can get good results with pot experiments after about four months. Personally I would not rely upon such a method after having used it, I do not think it gives a satisfactory solution of the problem put by manufacturers.

PROF. A. FRUHSTORFER (Germany): I have a few remarks to make on Dr. Raistrick's paper. I think the difference between us is that he is thinking of compounds and I am thinking of straight fertilisers. I want to give you an example of what happened in Germany. Five years ago a new complex fertiliser, was developed and tested and introduced into practice, with the formula 10-8-18 and with the phosphoric acid present in the form of dicalcium phosphate soluble in citric acid, evaluated with citric acid. After five years of use it turns out that the phosphoric acid is almost useless, because this fertiliser has been sold in granulated form and tested in powdered form, and granulation of fertilisers without water soluble phosphoric acid is useless.

MR. S. LARSEN (United Kingdom): I should like to ask Dr. Raistrick three questions, very short questions I hope. You say in your paper in the second paragraph on page 1:

"In our view phosphate applied to the soil can only be transferred from fertiliser to plant through the medium of the soil solution."

I should like to ask you if you have any evidence showing that.

DR. B. RAISTRICK (United Kingdom): Yes, there is evidence that it goes into the plants in ionic form. It is very difficult to describe it. It has not been published. I wonder whether Mr. Larsen has any evidence that it is not so.

MR. S. LARSEN (United Kingdom): Between the root and the soil you have a solution. You can call this solution a soil-solution; you could call it a plant-soil-solution. If you speak about the soil-solution, and if you could extract the water from the soil and determine the amount of P_2O_5 it contains you might have something of the order of 2 kilograms per hectare. If you use a crop for the same purpose, you will maybe have 25 or 50 kilograms more. In that case there must be another reaction between the soil and the plant roots. Both you and I know that.

MR. S. LARSEN (United Kingdom): You asked me for an explanation and this is one. I can give you several, but I will only use two. If you have a soil with a phosphate concentration of, say, 0.1 mg./litre soil solution, and you have another soil with 1.0, and you grow a crop on those two soils, you will predict a higher phosphate up-take from the latter soil, but the other case might be true in many cases.

MR. I. A. BROWNLIE (United Kingdom): Mr. Chairman, I just want to make a remark about Mr. Larsen's question on the sentence in the second paragraph of Dr. Raistrick's paper about "the fertiliser to plant through the medium of the soil solution". It occurs to me that one thing which might be interesting in this connection is a recent work published by Monsanto Chemicals Limited in America and

also, I believe, by some Russian workers. It is that on following up the application of liquid fertilisers to plants, the plant nutrients can be detected in the plant itself within a very short space of time, something of the order of 20 minutes or so.

THE CHAIRMAN (Interpretation): I think Mr. Larsen's point of view is supported by Jenny in "Soil Science" in 1938 where he said that the phyto-genic elements need not necessarily be in solution to be absorbed by the roots and that there may be a change when it is in contact with colloids of the soil and of the root surface.

MR. S. LARSEN (United Kingdom): The second question is, do you assume dicalcium phosphate as a stable compound in the soil?

DR. B. RAISTRICK (United Kingdom): The answer to that question, Mr. Chairman, is 'no'. I would give my reasons but they are rather complicated. However, the answer is 'no, very definitely no.'

MR. S. LARSEN (United Kingdom): I agree with you. I will now ask my third question. It is with reference to page 10 where you refer to some pot experiments telling us that you employ two soils, one with pH 5.0 and one with pH 7.6. The first one is called an acid soil - and I agree with you - and the second one is called a calcareous soil, but that might not be true if you did not have an estimation of the lime content of the soil, because you can have a high pH without any free calcium carbonate in the soil.

DR. B. RAISTRICK (United Kingdom): Mr. Chairman, the tests described in page 10 were done at the Jealott's Hill Research Station under the control of one of the United Kingdom's best soil scientists. I have his word for it that it was a calcareous soil. I do not have the full details of this soil, but I will supply them to Mr. Larsen if he so wishes.

MR. S. LARSEN (United Kingdom): Thank you very much indeed. I have one point regarding section 5. I think we can agree that only hydroxyapatite, which is a stable compound in the soil, of course, can be predicted by your method, as we can see from Table 5.

Finally, I should like to comment on the term "value". As you know, research workers at Rothamsted have used the term "superphosphate equivalents", and maybe the time is ripe to settle the term and find out what we should say in the future, ammonium phosphate or superphosphate equivalent or values.

DR. B. RAISTRICK (United Kingdom): I would suggest that superphosphate equivalent is not a very good term. I advise ammonium phosphate. Ammonium phosphate is a chemical compound which is easily made in a pure state; superphosphate can be anything, Gentlemen: it can be made from Florida rock, from Morocco or Kola rock, and to my mind it would not be a suitable compound for use as a yardstick in setting up a set of values.

MR. S. LARSEN (United Kingdom): In order to be neutral we use mono-calcium phosphate which we know very well cannot be more than one thing, namely mono-calcium phosphate.

DR. B. RAISTRICK (United Kingdom): I think I am right in saying that there is little or no production of pure mono-calcium phosphate in the world. Mono-calcium phosphate is only made for baking powders and so on, and in the United Kingdom at least, the material which is sold for baking powder is a mixture of an anhydrous body and a hydrate. If we had to use pure mono-calcium phosphate, it would have to be made specially for the job whereas ammonium phosphate is a worldwide known substance of purity.

MR. K. POLL (Holland): Mr. Chairman, in Holland we carried out experiments in this way comparing ammonium phosphate and superphosphate, and Dr. Raistrick's figures are not the same as those we obtained in Holland. Superphosphate has always given the same results, and in my opinion superphosphate is one of the best phosphatic fertilisers you can have in practice; perhaps not in pot experiments or in certain other cases. Ammonium phosphate is an acid fertiliser and, especially on acid soils, it has worse effect than superphosphate. So I do not believe the figures of Dr. Raistrick. If he says that superphosphate is the second best phosphate fertiliser, I do not agree with him. I mean, superphosphate is real SUPER phosphate!

THE CHAIRMAN (Interpretation): We thank Dr. Raistrick for his paper which has certainly brought out some differences of opinion.

PAPER LE/804 - "RAPID RADIO-METRIC DETERMINATION OF POTASH IN COMPOUND FERTILISERS" - by DR. K.C. SCHEEL (Germany)

THE CHAIRMAN: Have you any information to ask of Dr. Scheel with regard to his paper, LE/804.

MR. A. TALMI (Israel): Would this method also be applicable to the estimation of potash in aqueous solution?

DR. K.C. SCHEEL (Germany) (Interpretation): Yes, and there are also some remarks to be found in older literature in regard to that point. We are purposely not working in a solution in order to make the method even more rapid. In some cases it is advantageous to use an aqueous solution in particular cases where the phosphate contains uranium, because by using an aqueous solut on the uranium can be precipitated in alkaline solution. The solution has to be alkaline to ensure that all radio-active uranium compounds are precipitated.

MR. P. CRAVEN (United Kingdom): Mr. Chairman, may I ask Dr. Scheel two questions? The first is whether or not he has compared his method in the case of normal compound fertilisers with the flame photometric method. This particular method is gathering increased use, particularly when potassium is being determined on samples at the same time as the phosphate content, the phosphate being determined by colorimetric methods. Therefore, one has available solutions which can be used both for the phosphate determination and potash determination, so that it does not mean there is any great trouble in making the solution.

The second question is that in his paper he refers to a correction which has to be applied for the uranium content of super for the activity due to the uranium in the original rock and its disintegration products. What I should like to ask is whether or not this particular constant, 45 impulses min/% P₂O₅ for 77% land pebble phosphate, varies when triple-superphosphate is used instead of superphosphate? It would appear possible that some of the disintegration products are precipitated with the calcium phosphate and gypsum and filtered off when the phosphoric acid is being made.

DR. K.C. SCHEEL (Germany): The flame photometric method actually has to be regarded as a competitive method. We have carried out various experiments with a flame photometric method, but, insofar as pure potash salts are concerned, I am definitely of the opinion that the radio-metric method is better, and in addition I would say that the radio-metric method is a easier and simpler one, as far as the work is concerned.

The question becomes somewhat more difficult when you deal with compound fertilisers. There is, of course, one objection: that if you determine the phosphate at the same time, there are solutions

already present. In the case of the flame photometer, it is very sensible to impurities and in that case one is usually using standard solutions and it would be better, in that case, to apply the radio-metric method. In the case of triple-superphosphate, the radium is precipitated with gypsum and the rest of the uranium components remain in the triple-superphosphate and the activity is reduced. Therefore, it is best to use an apparatus which gauges according to the standardised triple-superphosphate.

MR. I.A. BROWNLIE (United Kingdom): Mr. Craven has raised the question of flame photometers which I had intended to raise myself, but I might add that in our experience with these two methods - flame photometer versus the radio-metric determination - where you are doing standard analyses on fertilisers and have already made up a solution for phosphate determination, it is preferable, in my opinion, to do the potash determination with the flame photometer.

However, there are other applications which I have in mind on the manufacturing side: for example, you can quickly check the percentage of potash in fresh batches of material coming into the plant. You can also determine whether there are any preferential losses of potash in various stages of manufacture, such as in cyclone dust or in dust extraction systems. In my opinion, the two methods are very valuable in fertiliser manufacture and control and should be used together.

MR. A. TALMI (Israel): Is the experiment necessary for the making of radio-metric determination of potassium commercially available and how much does it cost?

DR. K.C. SCHEEL (Germany): £200 roughly.

MR. I.A. BROWNLIE (United Kingdom): I should like to put in my bid, that the same apparatus which was discussed in a previous paper yesterday serves for these analyses, with the substitution of a β counter for a γ counter, costing a few more pounds in the United Kingdom.

PAPER LE/805: - "DETERMINATION OF ACID REQUIREMENT IN SUPERPHOSPHATE MANUFACTURE" by E. HERMAN, S. HAREL, B. PESKIN and A. TALMI.

THE CHAIRMAN (Interpretation): Have you any questions to ask Mr. Talmi about paper LE/805?

MR. A. TALMI (Israel): I have discovered two mistakes which I should like to point out. On page 4 there is an equation $A_u - A_c = \frac{49}{19} \times 0.80 \times \frac{70}{100} \times \%F$; it should be followed by "times the fluorine percentage".

On the same page - page 4 - towards the bottom, there is a line A_c , expressed as kg $P_{2O_5}/100$ kg rock. This is a mistake: it should be 'super' not 'rock'.

THE CHAIRMAN: Are there any remarks on that paper?

In the Chair: MR. D.J. BIRD

THE CHAIRMAN: I will now call on Mr. Charliers to sum up our various discussions from the points of view of the various agronomists.

MR. W. CHARLIER (Belgium) (Interpretation): First of all I wish to express my emotion at being asked to conclude the meetings because two years ago in Bordeaux this summary was given with great wit by Professor Albert Denolon who summarized the discussions with great ease and clarity. Unfortunately, it was the last meeting he could attend. I should like to recall a quip made by Professor Denolon two years ago when he said that the specialist becomes more competent as his field of activities narrows so that in the end he becomes a man who knows everything about nothing! This means that there is a danger in becoming too specialised and that experts have to co-ordinate their work.

Fortunately, owing to the initiative of our former President of the Association and Chairman of these meetings, Mr. D.J. Bird, we have been enabled to compare the various points of view of the Agronomists and the Technicians. I realise that, although the discussions were very active, there is not such a great discrepancy between their respective points of view, because both in their researches use experimental methods to obtain data from which to draw valuable conclusions. But when the discrepancy becomes wider and more defined is when the technicians have to deal with inert materials while the agronomists have to deal with living matter. The main difference between inert and living matter is that with inert materials you always have to deal with reproducible phenomena, whereas the living material is always subject to numerous different factors and conditions so that the methods of investigation become, of necessity, very subtle and complicated. We know very little about the various physiological mechanisms involved in living matter so that whenever a new method of investigation appears, such as radio-isotopes, we think we are in possession of a very much more subtle method, and should be able to give explanations to hitherto unsolved problems.

I believe much remains to be done on that subject and at our next meeting we shall have to consider it again because the discussions have shown that we are very far from the end of the research work.

With regard to the second section - the method of application of fertilisers - it might appear as if the points of view were very different, but they are different because the phenomena involved are also very different. The conclusion that can be reached is that you can use a granulated or other form of fertilisers under certain conditions and not under others, so that it is important to be able to define these conditions since we are unable to alter them. I wish to thank the delegates who have worked on this field of application because such papers as that presented by Professor Fruhstorfer, describing the effect of adding superphosphate to farmyard manure, have shown an unexpected increase in the effectiveness of the fertiliser with the result that yields are frequently very much increased even with a smaller fertiliser application. Therefore, the efficiency of the fertiliser is very much increased which may mean a better use of the fertiliser, greater outlets for the product in the future and a greater chance of favourable competition with other phosphatic fertilisers.

With regard to Section III - other nutrient elements - the situation is similar in that in certain cases you need only apply N.P.K. fertilisers whereas in others you must apply the secondary elements as well, depending upon the conditions. For instance, in the new countries where very little fertiliser has previously been applied, the problem of secondary elements may be very acute whereas in the old world where, for more than a century, large amounts of fertiliser have been used, elements such as sulphur, calcium and magnesium, have been applied to the soil as so-called impurities

with the result that deficiencies are seldom to be expected in these soils. In the tropics and in under-developed countries such deficiencies are very serious and may place a limit on the response to application of fertilisers in the usual way.

With regard to trace elements, the discussion has shown that these should be regarded more and more as medicines to cure deficiencies rather than as fertilisers. As to their methods of application, Mr. Clark of South Africa, and Mr. Poil of Holland, have shown that there are as many methods as conditions. The economic difficulties of applying trace elements are great and it is interesting that your attention has been drawn to the spraying of solutions of these elements, for most fields nowadays, are treated with insecticide or pesticide sprays, so that it would be easy to mix such trace elements with these sprays and apply them on the leaves. Applied in this way they would not be decomposed in the soil.

With regard to Section IV on rapid tests, the discussions have proved most profitable. Mr. Soubiès, for instance, has shown that these quick tests may be somewhat dangerous but Dr. Raistrick made a very interesting comment that such methods cannot give more information than they are asked to give. They can, at least, eliminate the bad products and leave the good ones for field experiments, thus saving time, trouble and labour. I think that at some future meeting we could consider the biological methods which have been used to ascertain the quantities of nutrient elements in the soil. I am thinking, in particular, of the Niklas method using *aspergillus niger* because such micro-organisms mobilise and assimilate nutrient elements from the soil in a manner much more similar to crop plants than do any of the chemical reagents we can devise such as water or ammonium citrate or other solutions which can only imitate very imperfectly what living matter can do.

In concluding this brief personal summary, I want to stress that I realise that collaboration between technicians and agronomists has been very profitable and very animated. Although the discussion was sometimes a little hard I think we shall derive very useful information from it.

DR. K. C. SCHEEL (Germany) Altogether sixteen papers have been presented to the meetings, and of those only five papers have dealt with the technical aspect of the subject. As a technician and a chemist I can understand that very well, but I would stress that both the technical people and the chemists are also in very close co-operation with the agricultural people. Mr. Charliers has given to this meeting a very detailed and interesting summary of all the discussions, and I can only say that I am in full agreement with Mr. Charliers.

I am now talking about the technical subjects, and in that connection I would refer to the paper by Mr. Brownlie which stressed particularly the possibility of the use of radio-active isotopes: the discussion which ensued was a sign of the great importance of this subject.

I would then refer particularly to the paper of Mr. Brook in which he discussed two new subjects which were of great interest to the meeting: first the method of granulation of mixed fertilisers and the effect of the granulation and the possibility of obtaining by means of graphs an exact picture of what has happened. The second point was the question of granulation tests carried out in the laboratory by which it was possible to evolve methods which led to quite a saving of labour.

In Mr. Brook's second paper he refers to the influence of moisture on granulation: in other words, the less the moisture content, the harder the granules. In this connection, I was rather sorry that the discussion did not enlarge more on the question of caking of granulated fertilisers in the heap.

As far as my own paper is concerned, I want to stress the great simplicity of tests if they are carried out on the basis of radio-activity.

Lastly I would refer to the paper by Mr. Talmi and his collaborators dealing with a simple method of determining the quantity of sulphuric acid to be used with various phosphates. This method is particularly interesting in cases where some companies are beginning to deal with new phosphates.

THE CHAIRMAN: Gentlemen, I am sure you will agree with me when I express our thanks to Mr. Charliers and to Dr. Scheel for their very able summaries of our two days of work. Personally I have listened to the discussions, the clashes and the exchanges of views with considerable interest. From time to time I did have a feeling that one of the possible difficulties was that certain countries are interested in selling superphosphate whereas other countries are more interested in selling superphosphate with nitrogen and potash in compound fertilisers.

Gentlemen, I want once again to express my own thanks and those of the Council to the writers of the various papers. Some of them, I realise, were not discussed in detail and did not arouse any questions, but I hope the writers will not feel depressed, because I am quite convinced that they were an essential part of the discussions under the various headings. I particularly want to thank the introducers who have had, I think, a difficult and, in some ways, a rather thankless task, but I feel that they have achieved their objects, as was evident by the subsequent discussions. I also want to thank the speakers who took part in the discussions, and in particular the gentlemen who took the Chair during the second, third and fourth sessions.

Then, Gentlemen, I know that without any hesitation you will join with me in expressing our very great thanks to Mr. Carpentier and Mr. Morgan for the very excellent way in which they have carried out their translation. It has indeed been a Herculean task and but for their efficiency our work here would have been largely nullified. (Applause)

I would ask Dr. New to accept from us, and to convey to the members of staff in the Paris and London offices, our appreciation of the work which they have put in in collecting the papers, having them translated and making the arrangements for this Conference.

I should also like to associate myself with the remarks of our President this morning, in expressing to our Swiss friends our very great appreciation of the hospitality which they have offered to us. I should also like to say on your behalf, and personally, how very much we have enjoyed having our guests here with us and have appreciated very much the part which they have taken in our discussions.

My final point is that when we opened this Conference I said that it was in the nature of an experiment. I think the way in which the meeting has developed, particularly the third and fourth discussions, has shown that we were learning by experience. I personally have a feeling - and I think it has been supported by the attendance and the discussions - that, as an experiment, it has not been a failure. One of the things which, to some extent, caused doubts in the minds of the Council when this matter was first ventilated was the possible chemical reaction between the agronomists and the technicians and their respective hardness of granule. But I would conclude by saying this: if you feel that this Conference has been worth while, then will you please let your delegates on the Council know, and if you have any suggestions whereby you think the procedure or method of conducting such a conference could be improved, will you also please pass those on to your country's delegate and ask him to raise the matter with Dr. New.

With those words, Gentlemen, I declare the First Joint Meeting of the Agronomists and Technicians closed, and I would thank you for your attendance.

(The Conference closed.)